

## 國立清華大學 111 學年度學士後醫學系單獨招生試題

考試科目：化學與物理

共 16 頁，第 1 頁 \*請在【答案卡】作答

Choose one best answer for the following questions

【單選題】每題 2.5 分，共計 150 分。答錯一題倒扣 0.625 分，未作答，不給分亦不扣分。1~30 題為化學，31~60 題為物理。

- One mole of an ideal gas undergoes an isothermal reversible expansion at 300 K. During this process, the system absorbs 450 J of heat from the surroundings. When this gas is compressed to the initial state in one step isothermally, twice as much work is done on the system as was performed on the surroundings during the expansion. Which of the following statements about these processes are correct?

I.  $\Delta S_{\text{sys}}$  for the one-step isothermal compression is 1.5 J/K.  
 II.  $\Delta S_{\text{surr}}$  for the one-step isothermal compression is 3.0 J/K.  
 III.  $\Delta S_{\text{univ}}$  for the reversible isothermal expansion is zero.  
 IV.  $\Delta S_{\text{univ}}$  for the overall process (expansion and compression) is zero.  
 V.  $\Delta S_{\text{surr}}$  for the overall process (expansion and compression) is  $-1.5$  J/K.

(A) I, II (B) II, III (C) II, III, IV (D) II, III, V (E) I, IV, V
- Which of the following statements about ligands, *d*-block metals, and coordination complexes is correct?

(A) The cyanate ion ( $\text{OCN}^-$ ) can have three different Lewis structures, in which all the N atoms have the same formal charge.  
 (B) Zinc is a component of vitamin B<sub>12</sub>, which is essential for the metabolism of carbohydrates, fats, and proteins.  
 (C)  $[\text{Co}(\text{NH}_3)_4\text{Cl}_2]^+$  has *cis-trans* isomers, and the *cis* isomer is optically active.  
 (D)  $[\text{Cr}(\text{en})(\text{NH}_3)_2\text{I}_2]^+$  (en = ethylenediamine) has three geometrical isomers.  
 (E) The octahedral  $\text{Cu}^{2+}$  complexes are more appropriate than the octahedral  $\text{Cr}^{2+}$  complexes to be used to determine the field strength of a ligand.
- Consider 1.0 mole of an ideal gas contained in a 2.0 L bulb at 27 °C. This bulb is connected to a 10.0 L sealed, initially evacuated bulb via a valve. When the valve is opened, the temperature is assumed to remain constant. Which of the following statements is *incorrect*? (gas constant  $R = 0.082 \text{ atm}\cdot\text{L}\cdot\text{K}^{-1}\cdot\text{mol}^{-1}$ )

(A) The final pressure at equilibrium will be 2.1 atm.  
 (B) The enthalpy change ( $\Delta H$ ) for this process is zero.  
 (C) This is a spontaneous process.  
 (D) Work does not occur during the expansion of this gas.  
 (E) The driving force for this process to occur is an increase in the internal energy.

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共 16 頁，第 2 頁 \*請在【答案卡】作答

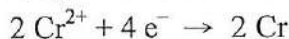
4. Compound X, like most substances, exhibits only three phases: solid, liquid, and vapor. The triple point of X is at 90 torr and 115 °C. Which of the following statements concerning the liquid and gaseous X is correct?

- (A) X(l) cannot exist at 1 atmosphere pressure.  
 (B) X(l) cannot exist above 115 °C.  
 (C) X(g) cannot exist below 115 °C.  
 (D) X(l) cannot have a vapor pressure greater than 90 torr.  
 (E) X(l) cannot exist at a pressure of 15 torr.

5. Given the following half-reactions and associated standard reduction potentials:



Calculate the standard reduction potential for the following half-reaction:



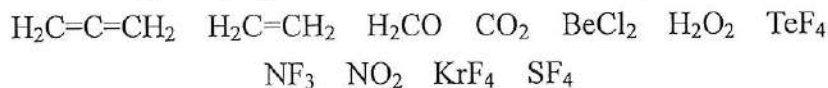
- (A) -0.23 V    (B) -0.46 V    (C) -0.85 V    (D) -1.23 V    (E) -1.70 V

6. How many of the following statements are correct?

- I. All the group 13 elements are metals.  
 II. Alkaline earth metals react less vigorously with water than do alkali metals.  
 III. Salts can consist of hydrogen.  
 IV. Because Li has a more negative standard reduction potential than Na and K, it reacts most quickly with water among these three alkali metals.  
 V. BeO is amphoteric.

- (A) 1    (B) 2    (C) 3    (D) 4    (E) 5

7. Given the following eleven gaseous molecules:



Which of the following statements about these molecules is correct?

- (A) There are six molecules with all their atoms lying in the same plane.  
 (B) Same hybridized orbitals are used by the N atoms in  $\text{NF}_3$  and  $\text{NO}_2$ .  
 (C) Both  $\text{TeF}_4$  and  $\text{KrF}_4$  are nonpolar molecules.  
 (D) All the C-atoms in the four carbon-containing molecules use  $sp^2$  hybridized orbital.  
 (E) Both  $\text{H}_2\text{O}_2$  and  $\text{NO}_2$  exhibit resonance.

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8. Ammonium benzoate is a salt formed from ammonia ( $\text{NH}_3$ ) and benzoic acid ( $\text{C}_6\text{H}_5\text{COOH}$ ). Calculate the pH of a 0.10 M solution of ammonium benzoate at 25 °C. ( $K_a = 6.4 \times 10^{-5}$  for  $\text{C}_6\text{H}_5\text{COOH}$ ,  $K_b = 1.8 \times 10^{-5}$  for  $\text{NH}_3$ ;  $\log 2 = 0.301$ ;  $\log 3 = 0.477$ ;  $\log 7 = 0.845$ )  
 (A) 4.74 (B) 5.96 (C) 6.73 (D) 7.28 (E) 8.04
9. Yellow phosphorus ( $\text{P}_4$ ) undergoes disproportionation in  $\text{NaOH}(\text{aq})$  to produce  $\text{PH}_3$  and  $\text{NaH}_2\text{PO}_2$ . If 16.0 g of  $\text{P}_4$  was used in the reaction, how many grams of  $\text{P}_4$  would behave as the oxidizing agent? (atomic weight of P = 31 u)  
 (A) 12.0 g (B) 10.0 g (C) 8.0 g (D) 6.4 g (E) 4.0 g
10. Consider the titration of 50.0 mL of 0.100 M  $\text{NaH}_2\text{PO}_4(\text{aq})$  with 0.100 M  $\text{NaOH}(\text{aq})$ . For  $\text{H}_3\text{PO}_4$ ,  $K_{a1} = 7.5 \times 10^{-3}$ ,  $K_{a2} = 6.0 \times 10^{-8}$ , and  $K_{a3} = 4.8 \times 10^{-13}$ . Three pH values during the titration are listed as follows.  
 (1) Before the addition of  $\text{NaOH}(\text{aq})$ , the pH is  $x$ .  
 (2) After the addition of 25.0 mL  $\text{NaOH}(\text{aq})$ , the pH is  $y$ .  
 (3) After the addition of 50.0 mL  $\text{NaOH}(\text{aq})$ , the pH is  $z$ .  
 Which of the following statements about  $x$ ,  $y$ , and  $z$  is correct?  
 ( $\log 2 = 0.301$ ,  $\log 3 = 0.477$ ,  $\log 5 = 0.699$ )  
 (A)  $x < 4$ ,  $y > 7$  (B)  $x > 4$ ,  $z > 10$  (C)  $y > 7$ ,  $z < 10$   
 (D)  $y > 8$ ,  $z > 9$  (E)  $x < 5$ ,  $y < 7$
11. Element X has only two isotopes, 1 and 2, and its atomic weight is  $y.33$  u. Of the following combinations of isotope abundance and corresponding neutron number, which is the most reasonable? (note:  $y$ ,  $z$ ,  $p$ ,  $q$  and  $r$  are integers)
- |     | isotope 1 |                   | isotope 2 |                   |
|-----|-----------|-------------------|-----------|-------------------|
|     | abundance | number of neutron | abundance | number of neutron |
| (A) | 50%       | $p$               | 50%       | $p + 0.66$        |
| (B) | 67%       | $y$               | 33%       | $y + 1$           |
| (C) | 75%       | $q$               | 25%       | $q + 2$           |
| (D) | 45%       | $r$               | 55%       | $r - 1$           |
| (E) | 83%       | $z$               | 17%       | $z + 2$           |
12. Which of the following molecular formulae has the most structural isomers, all containing a hydroxyl group?  
 (A)  $\text{C}_3\text{H}_6\text{O}$  (B)  $\text{C}_3\text{H}_8\text{O}$  (C)  $\text{C}_4\text{H}_8\text{O}$  (D)  $\text{C}_4\text{H}_{10}\text{O}$  (E)  $\text{C}_5\text{H}_{12}\text{O}$

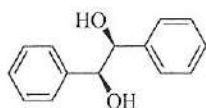
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考試科目：化學與物理

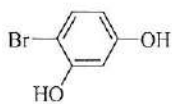
共 16 頁，第 4 頁 \*請在【答案卡】作答

13. Which of the following statements about the dominant Lewis structures of  $\text{ClO}_x^{n-}$  is correct?
- (A)  $\text{ClO}$  obeys the octet rule. (B)  $\text{ClO}^-$  has 1  $\pi$  bond.  
 (C)  $\text{ClO}_2^-$  has 8 lone pair electrons. (D)  $\text{ClO}_3^-$  has 2  $\pi$  bonds.  
 (E)  $\text{ClO}_4^-$  has 10 lone pair electrons
14. Which of the following statements about the van der Waals equation is *incorrect*?
- $$(P + \blacksquare)(V - \square) = nRT$$
- (A) The van der Waals equation describes the behavior of real gases.  
 (B)  $\blacksquare = n^2a/V^2$  and is used to compensate for the attraction force between gas molecules.  
 (C)  $\square = nb$  and is used to correct the volume of real gases.  
 (D)  $\blacksquare$  is negative for most gases.  
 (E)  $\square$  is positive for most gases.
15. If the reaction  $\text{A(g)} + 3 \text{B(s)} \rightleftharpoons 2 \text{C(g)} + \text{D(g)}$  starts with only 1 mole of A and 1 mole of B in a 1.0 L sealed reaction vessel, the equilibrium constant of this reaction is  $K$ . Which of the following statements is correct?
- (A) The expression for  $K$  of this reaction is  $([\text{C}]^2[\text{D}])/([\text{A}][\text{B}]^3)$ .  
 (B) If  $K = 1$ ,  $[\text{A}]$  is 0.5 M at equilibrium.  
 (C) If  $K = 1$ ,  $[\text{C}]$  is 0.3 M at equilibrium.  
 (D) If  $[\text{C}] = 0.5 \text{ M}$  at equilibrium,  $K = 0.08$ .  
 (E) If  $[\text{D}] = 0.25 \text{ M}$  at equilibrium,  $K = 0.17$ .
16. Which of the following comparisons for the acidity of the following species in an aprotic solvent is correct?
- (A) Acidity:  $\text{CH}_3\text{COO}^- > \text{HPO}_4^{2-}$  (B) Acidity:  $\text{NaNH}_2 > \text{NH}_3$   
 (C) Acidity:  $\text{HCO}_3^- > \text{HSO}_4^-$  (D) Acidity:  $\text{CH}_3\text{OH} > \text{NH}_4\text{Cl}$   
 (E) Acidity:  $\text{C}_6\text{H}_5\text{OH} > (\text{CH}_3)_3\text{COH}$

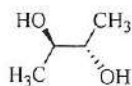
17. Which of the following compounds (1-5) is optically active?



1



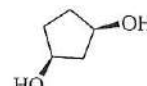
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3



4



5

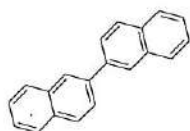
- (A) 1 (B) 2 (C) 3 (D) 4 (E) 5

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考試科目：化學與物理

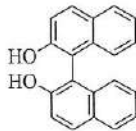
共 16 頁，第 5 頁 \*請在【答案卡】作答

18. Which of the following compounds (6-10) is chiral?



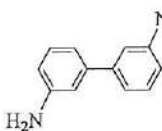
6

(A) 6



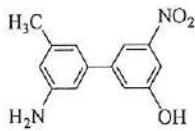
7

(B) 7



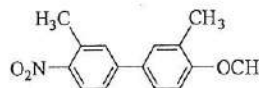
8

(C) 8



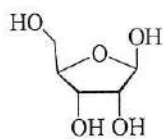
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(D) 9



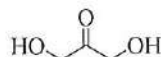
10

(E) 10

19. Which of the following compounds (11-15) is *not* monosaccharide?

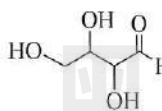
11

(A) 11



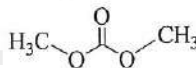
12

(B) 12



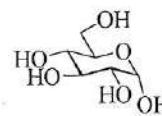
13

(C) 13



14

(D) 14



15

(E) 15

20. Each of the longest wavelength of the spectral lines recorded for two electron transitions from  $n = 2$  and  $n = 4$  of hydrogen atoms is X and Y, respectively. What is the relationship between X and Y?

(A)  $X:Y = 11:34$ (B)  $X:Y = 5:4$ (C)  $X:Y = 1:4$ (D)  $X:Y = 5:144$ (E)  $X:Y = 7:108$ 

21. As shown in Fig. 1, a container with a fixed volume at constant temperature is divided into three compartments (A, B, and C) by two partitions, which are movable without friction. Compartments A and C are filled with an equal amount of mass of gas X and Y. When two partitions stop sliding, the density of X is equal to that of Y. Which of the following statements is correct?

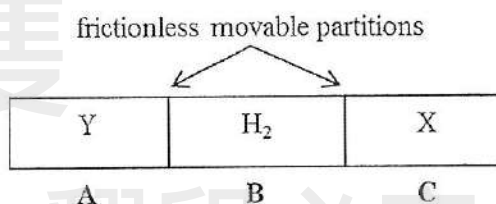


Fig. 1.

(A) Volume of gas:  $V(X) > V(H_2) > V(Y)$ (B) Number of moles of gas:  $n(X) < n(H_2) < n(Y)$ (C) Number of moles of gas:  $n(X) = n(H_2) = n(Y)$ 

(D) The molecular mass of X is equal to the molecular mass of Y.

(E) The molecular mass of X is smaller than the molecular mass of Y.

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 考試科目：化學與物理

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22. Which of the following groups of species can coexist in significant amounts in a given solution at room temperature?
- (A) A solution that turns methyl orange red contains  $\text{Mg}^{2+}$ ,  $\text{K}^+$ ,  $\text{SO}_4^{2-}$ , and  $\text{NO}_3^-$ .  
 (B) A solution that turns phenolphthalein red contains  $\text{Na}^+$ ,  $\text{Cu}^{2+}$ ,  $\text{HCO}_3^-$ , and  $\text{NO}_3^-$ .  
 (C) 0.1 M  $\text{AgNO}_3$  solution contains  $\text{H}^+$ ,  $\text{K}^+$ ,  $\text{SO}_4^{2-}$ , and  $\text{I}^-$ .  
 (D) 0.1 M  $\text{Na}[\text{Al}(\text{OH})_4]$  solution contains  $\text{H}^+$ ,  $\text{Na}^+$ ,  $\text{Cl}^-$ , and  $\text{SO}_4^{2-}$ .  
 (E) An acidic potassium permanganate solution contains  $\text{H}^+$ ,  $\text{Na}^+$ ,  $\text{SO}_4^{2-}$ , and glucose.

23. Under the same conditions, Na, Mg, and Al of equal molar amounts are respectively added to three test tubes X, Y, and Z containing the same concentration and volume of dilute hydrochloric acid to fully react at room temperature. Which of the following three test tubes X, Y and Z must be *incorrect* in relation to the volume of gas produced?
- (A)  $X(\text{Na}) > Y(\text{Mg}) > Z(\text{Al})$       (B)  $X(\text{Na}) > Y(\text{Mg}) = Z(\text{Al})$   
 (C)  $X(\text{Na}) < Y(\text{Mg}) < Z(\text{Al})$       (D)  $X(\text{Na}) = Y(\text{Mg}) = Z(\text{Al})$   
 (E)  $X(\text{Na}) < Y(\text{Mg}) = Z(\text{Al})$

24. A certain amount of  $\text{Cl}_2$  is introduced into a certain concentration of potassium hydroxide solution, where both reagents are completely consumed and heat is released. Three ionic species containing chlorine are produced from this reaction, among which the amount (n/mole) of  $\text{ClO}^-$  and  $\text{ClO}_3^-$  ions and the reaction time (t/s) are shown in Fig. 2.

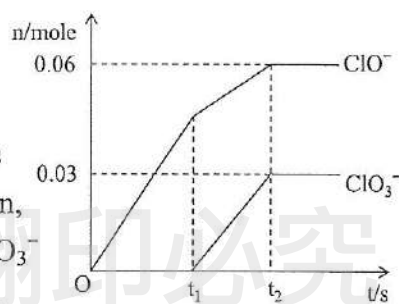


Fig. 2.

- Which of the following statements is *incorrect*?
- (A) Different reactions of  $\text{Cl}_2$  and potassium hydroxide solutions may occur at different temperatures.  
 (B) The number of electrons transferred in the reaction is  $1.26 \times 10^{23}$ .  
 (C) The amount of  $\text{KOH}$  in the original potassium hydroxide solution cannot be determined.  
 (D) The amount of  $\text{Cl}^-$  in the product is 0.21 mol.  
 (E) The amount of  $\text{K}^+$  in the solution is 0.30 mol.



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共 16 頁，第 7 頁 \*請在【答案卡】作答

25. Based on the following experiments, which substance can prove to be bleaching?
- (A) When chlorine is introduced into a NaOH solution with phenolphthalein, the solution immediately discolors.
- (B) When a small amount of  $\text{Na}_2\text{O}_2$  powder is added to the water with phenolphthalein, the solution first turns red and then discolors.
- (C) The red color of phenolphthalein solution fades after the addition of  $\text{SO}_2$ .
- (D) When  $\text{SO}_2$  is added to an acidic solution of  $\text{KMnO}_4$ , the purple color of the solution fades.
- (E) Addition of nitric acidified  $\text{AgNO}_3$  solution to chlorine water results in white precipitate.
26. Two bottles of gas are  $\text{NO}_2(\text{g})$  and  $\text{Br}_2(\text{g})$  with the same appearance. A chemist designed a variety of identification methods:
- I. wet test paper with starch/KI,    II. addition of a small amount of NaCl solution,  
 III. addition of a small amount of  $\text{AgNO}_3$  solution,  
 IV. addition of a small amount of water and then an appropriate amount of benzene,  
 V. change the temperature
- Which methods can be used to distinguish  $\text{NO}_2(\text{g})$  from  $\text{Br}_2(\text{g})$ ?
- (A) I, III, IV    (B) II, III, IV    (C) I, II, III, IV    (D) I, II, III, V    (E) II, III, IV, V
27. At 298 K and 101 kPa,  $2 \text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2 \text{SO}_3(\text{g}) \Delta H = -197 \text{ kJ} \cdot \text{mol}^{-1}$ . At the same temperature and pressure, 2 moles of  $\text{SO}_2$  and 1 mole of  $\text{O}_2$  are introduced into a closed container, and when equilibrium is reached, the amount of heat given off is  $Q_1$ . If 1 mole of  $\text{SO}_2$ , 0.5 mole of  $\text{O}_2$  and 1 mole of  $\text{SO}_3$  are introduced into a container of the same volume, and the amount of heat given off at equilibrium is  $Q_2$ , which of the following relationships is correct?
- (A)  $Q_2 < Q_1 < 197 \text{ kJ}$     (B)  $Q_2 > Q_1 > 197 \text{ kJ}$     (C)  $Q_2 = Q_1 = 197 \text{ kJ}$   
 (D)  $Q_1 < Q_2 < 197 \text{ kJ}$     (E)  $Q_2 = Q_1 < 197 \text{ kJ}$
28. After electrolyzing a certain concentration of copper sulfate solution with an inert electrode at a certain temperature for a certain period of time, 0.1 mole of basic copper carbonate  $[\text{Cu}_2(\text{OH})_2\text{CO}_3]$  is added to the resulting solution, and the concentration and pH are restored to exactly the same level as before electrolysis (without considering the dissolution of carbon dioxide). What is the total number of electrons transferred during the electrolysis?
- (A) 0.4 mole    (B) 0.5 mole    (C) 0.6 mole    (D) 0.7 mole    (E) 0.8 mole

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共 16 頁，第 8 頁 \*請在【答案卡】作答

29. Acetic acid is an electrolyte. Which of the following facts indicate that acetic acid is a weak electrolyte?
- ① Acetic acid and water are miscible in any ratio.
  - ② Acetic acid solution conducts electricity.
  - ③ Acetic acid molecules are present in acetic acid solution.
  - ④ The pH of 0.1 M acetic acid solution is greater than that of 0.1 M hydrochloric acid.
  - ⑤ Acetic acid reacts with calcium carbonate to give off  $\text{CO}_2$ .
  - ⑥ The pH of 0.1 M sodium acetate solution = 8.9.
  - ⑦ When zinc grains of the same size react with the same concentration of hydrochloric acid and acetic acid solution, the acetic acid starts to produce  $\text{H}_2$  at a slower rate.
- (A) ②⑥⑦    (B) ③④⑤⑥    (C) ③④⑥⑦    (D) ②④⑥⑦    (E) ①②

30. Five different types of chemical bonds in the molecular structure of ethanol are shown in Fig. 3. Which of the following statements about reactions in which ethanol breaks bonds is *incorrect*?

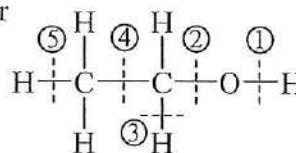


Fig. 3.

- (A) Bond ① breaks upon reaction with sodium metal.
  - (B) Bond ② and bond ⑤ break, when heating with concentrated sulfuric acid to  $170^\circ\text{C}$ .
  - (C) Only bond ② breaks, when heating with concentrated sulfuric acid to  $140^\circ\text{C}$ .
  - (D) Bond ① and bond ③ break upon reaction with  $\text{O}_2$  catalyzed by copper.
  - (E) Only bond ① breaks, when reacting with carboxylic acids in the presence of concentrated sulfuric acid.
31. Which of the following values is closest to the average translational kinetic energy of one mole of  $\text{N}_2$  gas at a temperature of  $27^\circ\text{C}$ ? The Boltzmann constant is  $1.38 \times 10^{-23} \text{ m}^2 \cdot \text{kg} \cdot \text{s}^{-2} \cdot \text{K}^{-1}$ .
- (A) 500 J    (B) 1000 J    (C) 2000 J    (D) 4000 J  
(E) information is not sufficient to answer



## 國立清華大學 111 學年度學士後醫學系單獨招生試題

考試科目：化學與物理

共 16 頁，第 9 頁 \*請在【答案卡】作答

32. A 50-kg boy runs up the stairs to the top of the 200-m tall 18 Peaks Mountain in 8 minutes and 20 seconds. Which of the following values is closest to his average power output in horse power? ( $g = 10 \text{ m/s}^2$ ,  $1 \text{ hp} = 750 \text{ W}$ )  
 (A) 0.4 (B) 0.3 (C) 2.0 (D) 10.0 (E) 50.0

33. A magnetron in a microwave oven emits electromagnetic waves with frequency  $f = 2450 \text{ MHz}$ . Which of the following values in Gauss is closest to the magnetic field strength required for electrons to move in circular paths with this frequency?  
 (A) 5 (B) 50 (C) 200 (D) 600 (E) 900

34. Suppose two parallel plates in Fig. 4, each has an area of  $100 \text{ cm}^2$  and are  $0.1 \text{ cm}$  apart. The capacitor is connected to a power supply and charged to a potential difference  $V_0 = 3000 \text{ V}$ . It is then disconnected from the power supply. Which of the following values is closest to the total energy (U) stored in the capacitor in J?  
 (A)  $8.0 \times 10^{-2}$  (B)  $3.0 \times 10^{-3}$  (C)  $6.0 \times 10^{-3}$   
 (D)  $1.0 \times 10^{-4}$  (E)  $4.0 \times 10^{-4}$

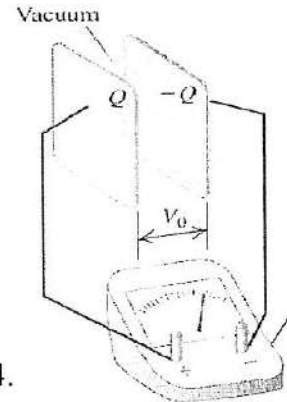


Fig. 4.

35. A heat pump does work  $W$  to bring heat  $Q_L$  from the cold outside (at constant temperature  $T_L$ ) and deliver heat  $Q_H$  to warm the interior at constant temperature  $T_H$ . Which of the following is wrong?

- (A) The coefficient of performance  $\text{COP} = \frac{Q_H}{W}$  (B)  $W = Q_H - Q_L$   
 (C)  $\text{COP} < 1.0$  (D) Ideally  $\text{COP} = \frac{T_H}{T_H - T_L}$  (E)  $Q_H > Q_L$

36. Which of the following values is closest to the minimum power in hp required for a 1000-kg car that is climbing a  $5.7^\circ$  hill at a steady  $72 \text{ km/h}$ ? Assume that the average drag force on the car at that speed is  $500 \text{ N}$  throughout.  
 ( $g = 10 \text{ m/s}^2$ ,  $1 \text{ hp} = 750 \text{ W}$ )  
 (A) 5 (B) 20 (C) 40 (D) 100 (E) 300

## 國立清華大學 111 學年度學士後醫學系單獨招生試題

考試科目：化學與物理

共 16 頁，第 10 頁 \*請在【答案卡】作答

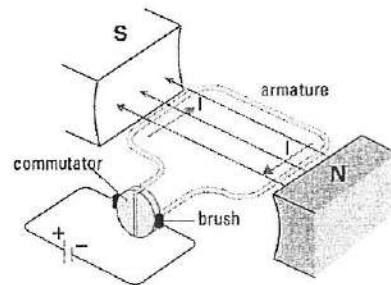
37. Which of the following values is closest to the total electric potential energy of 1 mole of  $\text{H}_2\text{O}$ ? For simplicity in calculation, here we assume a pure ionic bonding (H carries a charge  $+e$ ; O,  $-2e$ ), the O-H bond length  $\cong 100$  picometers, and the H-O-H bond angle is  $180^\circ$ .

- (A) 4.8 kJ/mol                      (B) 24 kJ/mol                      (C) 48 kJ/mol  
(D) 240 kJ/mol                      (E) 480 kJ/mol

38. Suppose an electron is trapped in a one-dimensional infinite well of width  $L = 2$  nm:  $U = 0$  from 0 to  $L$ ,  $U = \infty$  everywhere else. Obviously the particle can never climb out of well. Which of the following values is closest to the energy of the photon (in eV) that emits when the electron make the transition from level  $n = 4$  to  $n = 3$ . ( $h = 6.6 \times 10^{-34}$  m<sup>2</sup>kg/s;  $m_e = 9.1 \times 10^{-31}$  kg)

- (A) 0.02                      (B) 0.06                      (C) 0.2                      (D) 0.6                      (E) 2.0

39. A simple DC motor run by a 9.0 V battery has a 20 turn square coil with sides of length 5.0 cm and total resistance of  $24 \Omega$  (Fig. 5). When the motor spins, the magnetic field felt by the wire in the coil is  $2.0 \times 10^{-2}$  T. Which of the following values is closest to the the maximum torque on the motor in m·N? Fig. 5.



- (A)  $4 \times 10^{-4}$                       (B)  $1 \times 10^{-4}$                       (C)  $7 \times 10^{-3}$                       (D)  $2 \times 10^{-3}$                       (E)  $1 \times 10^{-2}$

40. A helicopter rotor blade can be considered as a long thin rod, as shown in Fig. 6. If each of the three-rotor helicopter blades is 3.75 m long and has a mass of  $m = 1.60 \times 10^2$  kg, which of the following value is closest to the moment of inertia of the three rotor blades about the axis of rotation in  $\text{kg} \cdot \text{m}^2$ ?

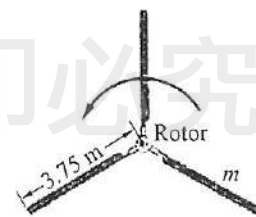


Fig. 6.

- (A) 5000                      (B) 2000                      (C) 1000                      (D) 100                      (E) 20

41. Car A leaves point  $O$  at  $t = 0$  and travels counterclockwise along a quarter circle of radius 100 m at constant speed 30.0 m/s to reach point  $P$ . Car B is supposed to leave point  $O$  and travels to point  $P$  at the same speed but along a straight line. At what time should car B leave point  $O$  in order to arrive at point  $P$  at the same time as car A?

- (A)  $t = -4.71$  s                      (B)  $t = -0.53$  s                      (C)  $t = 0$                       (D)  $t = 0.53$  s                      (E)  $t = 4.71$  s

## 國立清華大學 111 學年度學士後醫學系單獨招生試題

考試科目：化學與物理

共 16 頁，第 11 頁 \*請在【答案卡】作答

42. In a one dimensional problem, an object of mass  $m = 2.0$  kg is under effect of a resultant force  $F_x$  as shown in Fig. 7. If the object passes through the origin ( $x = 0.0$  m) with initial velocity  $v_0 = -2.0$  m/s at  $t = 0$ , what is the velocity at  $t = 4.0$  s?

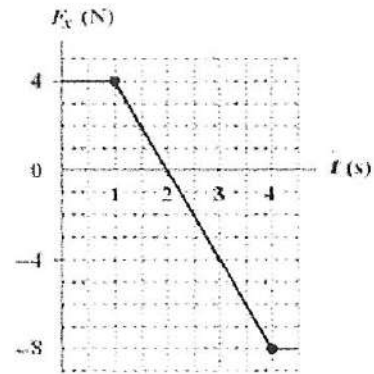


Fig. 7.

43. A spaceship of mass  $m$  circles a planet (mass =  $M$ ) in an orbit of radius  $R$ . How much energy is required to transfer the spaceship to a circular orbit of radius  $3R$ ?

(A)  $\frac{GmM}{3R}$     (B)  $\frac{GmM}{2R}$     (C)  $\frac{2GmM}{3R}$     (D)  $\frac{GmM}{9R}$     (E)  $\frac{4GmM}{9R}$

44. Two blocks,  $m_1 = 1.0$  kg and  $m_2 = 2.0$  kg, are connected by a light string as shown in Fig. 8. The radius of the pulley is 0.2 m and its moment of inertia is  $0.2 \text{ kg}\cdot\text{m}^2$ . If there is no slipping between the pulley and the string, what is the acceleration of block  $m_1$ ?

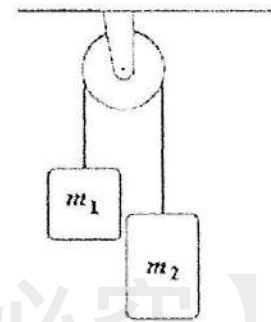


Fig. 8.

45. A wave is transmitted along a string.

Which of the following actions can quadruple the energy transmitted per unit time?

- I. double the frequency  
 II. double the tension of the string  
 III. double the amplitude  
 IV. double the wave velocity  
 V. quadruple the frequency  
 VI. quadruple the amplitude

(A) III, V    (B) II, III, V    (C) I, VI    (D) I, III    (E) I, II, III

## 國立清華大學 111 學年度學士後醫學系單獨招生試題

考試科目：化學與物理

共 16 頁，第 12 頁 \*請在【答案卡】作答

46. An empty can and a full can of the same shape are rolled side-by-side down an incline without slipping. If they start together at the same height, which of the following statements is correct?
- (A) The empty can arrives at the bottom first.  
 (B) The full can arrives at the bottom first.  
 (C) They both will arrive at the bottom together because the gravity acceleration is the same.  
 (D) It depends on the materials of the cans.  
 (E) It depends on the incline angle.
47. An ideal gas is allowed to undergo a free expansion from volume  $V_1$  to volume  $V_2$ , what is the change in entropy?
- (A) 0    (B)  $nRV_2/V_1$     (C)  $nR(V_2 - V_1)$     (D)  $nR \ln \frac{V_2}{V_1}$     (E)  $nRT \ln \frac{V_2}{V_1}$
48. There is a parallel-plate capacitor of capacitance  $C_0$ . A slab of dielectric material with  $\kappa = 2$  is placed into the gap between the plates, filling the bottom half of the gap. What is the resulting capacitance?
- (A)  $\frac{1}{2}C_0$     (B)  $\frac{3}{4}C_0$     (C)  $\frac{4}{3}C_0$     (D)  $2C_0$     (E)  $3C_0$
49. Electromagnetic wave is travelling in the free space with the amplitudes of the electric and magnetic fields as  $E_{\max}$  and  $B_{\max}$ , respectively. What is the average energy density in the space?
- (A)  $\frac{B_{\max}^2}{\mu_0}$     (B)  $\frac{B_{\max}^2}{4\mu_0}$     (C)  $\epsilon_0 E_{\max}^2$     (D)  $\frac{\epsilon_0 E_{\max}^2}{2} + \frac{B_{\max}^2}{2\mu_0}$     (E)  $\frac{\epsilon_0 E_{\max}^2}{4} + \frac{B_{\max}^2}{4\mu_0}$
50. Which of the following observations in the photoelectric effect experiment can be explained by the wave behavior of light?
- (A) There is a cutoff frequency below which no photoelectric current can be observed.  
 (B) Photoelectric current increases with increasing the intensity of the light.  
 (C) There is a stopping potential for photoelectric current regardless the intensity of the light.  
 (D) Dependence of ejection of electrons on light frequency.  
 (E) Dependence of photoelectron kinetic energy on light frequency.

## 國立清華大學 111 學年度學士後醫學系單獨招生試題

考試科目：化學與物理

共 16 頁，第 13 頁 \*請在【答案卡】作答

51. Two blocks of equal mass  $m$  placed on a frictionless flat surface are connected by a massless spring of a spring constant  $k$ , see Fig. 9. In the beginning, the spring is at its natural length, while the mass on the left is at rest and the mass on the right is moving towards right with a speed of  $v$ . The two-mass system would go on moving and oscillating relatively. During the oscillation, the maximum extension of the spring is  $L$ . What is the minimum value of the kinetic energy of the two-mass system during the oscillation?



Fig. 9.

- (A)  $\frac{mv^2}{4} + \frac{kL^2}{2}$  (B)  $\frac{mv^2}{2} + \frac{kL^2}{2}$  (C)  $\frac{mv^2}{2} - \frac{kL^2}{4}$  (D)  $\frac{mv^2}{4} - \frac{kL^2}{2}$  (E)  $\frac{mv^2}{4}$
52. The simple harmonic motion is a general phenomenon that occurs as one perturbs a system at stable equilibrium slightly away from its potential minimum. Estimate the period of the simple harmonic motion for a particle of mass  $m$  experienced a potential energy of the form  $U(x) = a(1/x + b^2x)$  (Joule) as the particle is slightly pushed away from  $x_0 = \frac{1}{b}$  (m), where  $x$  is the spatial coordinate of the particle.
- (A)  $2\pi\sqrt{\frac{4m}{ab^3}}$  (B)  $2\pi\sqrt{\frac{2m}{ab^3}}$  (C)  $2\pi\sqrt{\frac{m}{ab^3}}$  (D)  $2\pi\sqrt{\frac{m}{2ab^3}}$  (E)  $2\pi$
53. Two strings of different linear mass density are joined at  $x = 0$  to form a new string. The heavier string and the lighter string are on the left and right hand side of  $x = 0$ , respectively. Now, we keep the string stretched with a fixed weight, and send a wave from the heavier end to the lighter end. Which of the following statements is correct?
- (A) As the wave travels to the lighter end, its profile is amplified.  
 (B) As the wave travels to the lighter end, its speed decreases.  
 (C) As the wave hits  $x = 0$ , the reflected wave travels faster in the heavier string.  
 (D) The speed of the traveling wave remains the same regardless of which ends.  
 (E) As the wave hits  $x = 0$ , there is no reflected wave.

## 國立清華大學 111 學年度學士後醫學系單獨招生試題

考試科目：化學與物理

共 16 頁，第 14 頁 \*請在【答案卡】作答

54. Two different gases of similar mass density at room temperature react differently as the pressure is varied. Specifically, as the external pressure is raised from 1 atm to 1.01 atm, the volume of gas  $A$  is reduced by 0.1% while the volume of gas  $B$  is reduced by 0.2%. Which of the following statements is true?

- (A) The sound speed of gas  $A$  is faster.  
 (B) Low frequency sound waves travel faster than the high frequency ones in gas  $A$ .  
 (C) Low frequency sound waves travel slower than the high frequency ones in gas  $A$ .  
 (D) For the same sound source of frequency  $f$ , the frequency changes more as it enters gas  $B$ .  
 (E) As we reduce the pressure, the volume of the gas does not always increase.

55. Two ambulances have identical sirens that would make sound waves of frequency 700 Hz. A stationary observer is in the straight line and in between these two ambulances, while one ambulance is parked and the other is moving away the observer. The observer notices that the combined sound wave exhibits a beat frequency of 20 Hz. What is the speed of the ambulance moving away from the observer? Take the speed of sound to be 340 m/s, and there is no wind blowing during the observation.

- (A) 5 m/s      (B) 10 m/s      (C) 12 m/s      (D) 17 m/s      (E) 18 m/s

56. Given a non-uniform charge distribution  $\rho(r) = a/r$  ( $\text{C/m}^3$ ) between two concentric spheres of radius  $R$  and  $2R$ , and it is enclosed by a thin metal spherical shell of radius  $2R$  (negligible thickness) as shown in Fig. 10, what is the surface charge density on the inner surface of the metal shell?

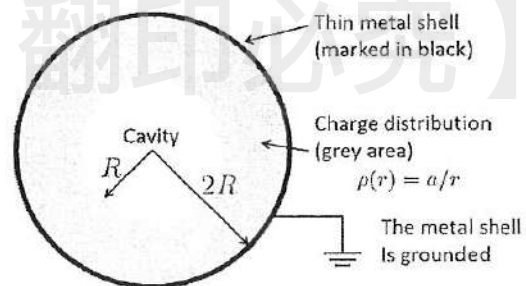


Fig. 10.

- (A)  $-\frac{3}{8}a$       (B)  $-\frac{3}{8}\frac{a}{\epsilon_0}$       (C)  $-\frac{5}{18}a$       (D)  $-\frac{5}{18}\frac{a}{\epsilon_0}$       (E)  $-\frac{3}{4}\frac{a^2}{R}$



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考試科目：化學與物理

共 16 頁，第 15 頁 \*請在【答案卡】作答

57. A charging RC circuit consists of a battery with emf  $\mathcal{E}$ , a resistor  $R$ , and two capacitors  $C_1$  and  $C_2$  as shown in Fig. 11. The two capacitors are identical when there are no dielectrics inserted (that is  $C_1 = C_2 = C_0$  when placed in vacuum). In order to increase the capacitance, we place a dielectric material of the dielectric constant  $\kappa$  in  $C_2$ . At  $t = 0$ , there are no charges in capacitors, and we close the switch to charge these capacitors. Which of the following statements is correct?

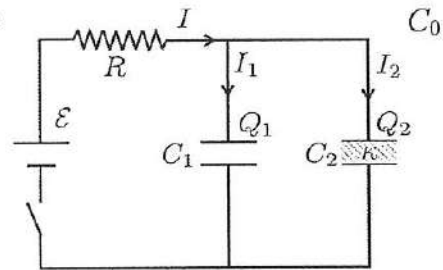


Fig. 11.

- (A) The charging percentage ( $Q/Q_{max}$ ) of these two capacitors would be the same at all times.
- (B) The maximum charges stored in these two capacitors would be the same.
- (C) The charging time would reduce if a larger resistor is used.
- (D) The charging time would reduce if a battery with a larger emf is used.
- (E) As more and more charges are stored in the capacitors, we expect the current flowing through the resistor is getting larger and larger.

58. A metal rod is pulled to the right in a uniform magnetic field  $B_0 \hat{z}$  so that it accelerates at a constant acceleration  $a \hat{x}$  on rails and forms a closed circuit with a resistor  $R$  as shown in Fig. 12. For simplicity, let us say at  $t = 0$ , the metal rod coincides with the resistor at  $x = 0$  and is at rest. The distance between rails is  $L$ . Assume that there is no friction between the rod and rails. Which of the following statements is correct?

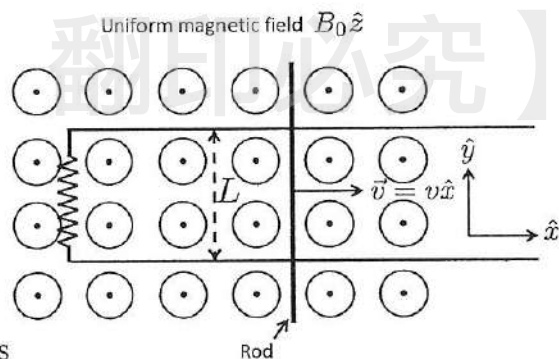


Fig. 12.

- (A) The emf induced by pulling the metal rod is proportional to  $t^2$ .
- (B) The force required to pull the metal rod is proportional to  $t$ .
- (C) The power dissipation in resistor is proportional to  $t^3$ .
- (D) The work done by the pulling force is proportional to  $t$ .
- (E) None of the above is correct.

## 國立清華大學 111 學年度學士後醫學系單獨招生試題

考試科目：化學與物理

共 16 頁，第 16 頁 \*請在【答案卡】作答

59. Which of the following statements about electromagnetic (EM) waves radiated from a point source with a fixed power is correct?
- (A) The amplitude of the electric field strength of the EM wave decays with distance squared.
- (B) The power received by a detector placed along the radial direction decays with distance.
- (C) The energy flux density decays with distance squared.
- (D) The larger the power radiated by the source is, the shorter the wavelength of the EM wave is.
- (E) The amplitude of the magnetic field strength of the EM wave does not depend on distance.

60. The PV curve for the van der Waals equation at a fixed temperature is plotted in Fig. 13. In this case, the liquid phase can coexist with the gas phase at pressure  $P_C$ . The pressure  $P_C$  intercepts with the PV curve at three points:  $a$ ,  $c$ , and  $e$ , respectively. And the slope of the PV curve vanishes at  $b$  and  $d$ . Which of the following statements is correct?

- (A) For pressure a bit higher than  $P_C$ , it is impossible to have a stable gas phase.
- (B) For pressure a bit lower than  $P_C$ , the gas phase is more stable than the liquid phase.
- (C) The region  $a \rightarrow b$  is the supercooled liquid region.
- (D) The region  $b \rightarrow c \rightarrow d$  corresponds to a fluid with a positive compressibility.
- (E) None of the above.

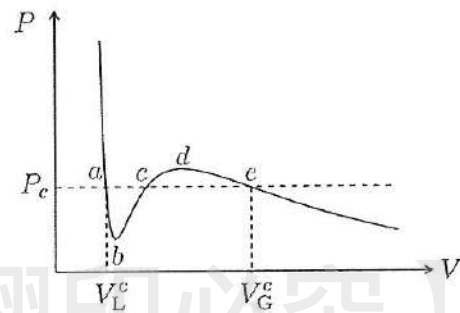


Fig. 13.

## 國立清華大學學士後醫學系考試 各科試題參考答案

科目名稱：化學與物理

題號	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
答案	B	D	E	E	C	C	A	C	E	C	E	C	D	D	D
題號	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
答案	E	A	B	D	E	D	A	A	C	B	E	A	C	C	C
題號	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
答案	D	B	E	E	C	C	E	D	A	B	D	B	A	E	D
題號	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
答案	B	D	C	E	B	E	D	A	A	B	A	A	B	C	B

## 國立清華大學 111 學年度學士後醫學系招生考試試題答案疑義釋疑公告

科目	題號	釋疑答覆	釋疑結果
化學與物理	11	題目清楚，答案正確。每一個元素都有質子，所以(B)選項不正確。	維持原答案 (E)
	15	題目清楚，答案正確。在(B)選項的條件下，物質 B 會入不敷出，所以不正確。	維持原答案 (D)
	23	題目清楚，答案正確。若酸不足量，三種金屬與酸反應後都過量時，因為鎂、鋁只和酸反應，所以 Y 和 Z 兩支試管得到的氫氣體積相同；鈉不僅和酸反應還和水反應，所以 X 試管的氫氣來自於水和酸，導致甲試管得到的氫氣體積大於 Y、Z 兩支試管得到的氫氣，故 B 可能。	維持原答案 (A)
	24	題目清楚，答案正確。由圖中數據得知生成 0.03 mole $\text{ClO}_3^-$ 和 0.06 mole $\text{ClO}^-$ ，故轉移電子數為 $(0.03 \times 5 + 0.06) N_A = 0.21 N_A$ ( $N_A = 6.0 \times 10^{23}$ ) = $1.26 \times 10^{23}$ 。	維持原答案 (C)
	26	題目清楚，答案正確。I. 兩種氣體都能氧化 KI 生成 $\text{I}_2$ ，現象相同；II. $\text{NO}_2$ 中加入少量 NaCl 溶液， $\text{NO}_2$ 與 $\text{H}_2\text{O}$ 反應得無色溶液， $\text{Br}_2$ 中加入少量 NaCl 溶液，溶液呈紅棕色。	維持原答案 (E)
	28	題目清楚，答案正確。本題除了電解銅，也電解水，所以過程中共有 0.6 mole 的電子轉移。	維持原答案 (C)
	37	題目清楚，選項(E)中的數值確實是最接近題目所要求的答案。	維持原答案 (E)
50	題目清楚，答案正確。光電效應有一些現象也是可以用波動理論解釋。	維持原答案 (B)	

## 化學

梁傑(梁家榮)老師提供

B

1. One mole of an ideal gas undergoes an isothermal reversible expansion at 300 K. During this process, the system absorbs 450 J of heat from the surroundings. When this gas is compressed to the initial state in one step isothermally, twice as much work is done on the system as was performed on the surroundings during the expansion. Which of the following statements about these processes are correct?
- I.  $\Delta S_{\text{sys}}$  for the one-step isothermal compression is 1.5 J/K.  
 II.  $\Delta S_{\text{surr}}$  for the one-step isothermal compression is 3.0 J/K.  
 III.  $\Delta S_{\text{univ}}$  for the reversible isothermal expansion is zero.  
 IV.  $\Delta S_{\text{univ}}$  for the overall process (expansion and compression) is zero.  
 V.  $\Delta S_{\text{surr}}$  for the overall process (expansion and compression) is -1.5 J/K.  
 (A) I, II (B) II, III (C) II, III, IV (D) II, III, V (E) I, IV, V

State 1  $\xrightarrow[\text{恆溫可逆膨脹}]{q = +450 \text{ J}, W = -450 \text{ J}}$  State 2  $\xrightarrow[\text{恆溫一步壓縮}]{q = -900 \text{ J}, W = +900 \text{ J}}$  State 1

$$\Delta S = \frac{450}{300} = +1.5 \frac{\text{J}}{\text{K}} \quad \Delta S = -1.5 \frac{\text{J}}{\text{K}}$$

$$\Delta S_{\text{surr}} = -1.5 \frac{\text{J}}{\text{K}} \quad \Delta S_{\text{surr}} = \frac{900}{300} = +3 \frac{\text{J}}{\text{K}}$$

$$\Delta S_{\text{univ}} = 0 \frac{\text{J}}{\text{K}} \quad \Delta S_{\text{univ}} = +1.5 \frac{\text{J}}{\text{K}}$$

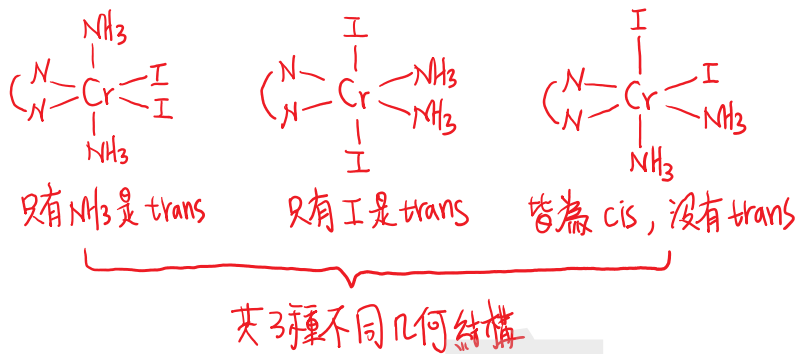
overall  $\Delta S_{\text{univ}} = +1.5 \frac{\text{J}}{\text{K}}$

結論: II、III 正確

D

2. Which of the following statements about ligands, *d*-block metals, and coordination complexes is correct?
- (A) The cyanate ion ( $\text{OCN}^-$ ) can have three different Lewis structures, in which all the N atoms have the same formal charge.  
 (B) Zinc is a component of vitamin  $\text{B}_{12}$ , which is essential for the metabolism of carbohydrates, fats, and proteins.  
 (C)  $[\text{Co}(\text{NH}_3)_4\text{Cl}_2]^+$  has *cis-trans* isomers, and the *cis* isomer is optically active.  
 (D)  $[\text{Cr}(\text{en})(\text{NH}_3)_2\text{I}_2]^+$  (*en* = ethylenediamine) has three geometrical isomers.  
 (E) The octahedral  $\text{Cu}^{2+}$  complexes are more appropriate than the octahedral  $\text{Cr}^{2+}$  complexes to be used to determine the field strength of a ligand.

- (A) 錯誤 · cyanate ion 的共振式中 · N atom 的形式電荷並沒有完全相同  
 (B) 錯誤 · vitamin  $\text{B}_{12}$  當中的重要成分是 Cobalt  
 (C) 錯誤 ·  $[\text{Cr}(\text{NH}_3)_4\text{Cl}_2]^+$  的 *cis* isomer 屬於 optically inactive  
 (D) 正確



(E) 錯誤 · Cu<sup>2+</sup> 為 d<sup>9</sup> complex · 沒有 high spin 或 low spin 差異 · 不適合用來決定 ligand 的 field strength  
 Cr<sup>2+</sup> 為 d<sup>4</sup> complex · high spin 或 low spin 有差異 · 可以用來決定 ligand 的 field strength

E

3. Consider 1.0 mole of an ideal gas contained in a 2.0 L bulb at 27 °C. This bulb is connected to a 10.0 L sealed, initially evacuated bulb via a valve. When the valve is opened, the temperature is assumed to remain constant. Which of the following statements is *incorrect*? (gas constant R = 0.082 atm·L·K<sup>-1</sup>·mol<sup>-1</sup>)
- (A) The final pressure at equilibrium will be 2.1 atm.
  - (B) The enthalpy change ( $\Delta H$ ) for this process is zero.
  - (C) This is a spontaneous process.
  - (D) Work does not occur during the expansion of this gas.
  - (E) The driving force for this process to occur is an increase in the internal energy.

(A) 正確

$$P_1 V_1 = nRT_1 \text{ 且 } P_1 V_1 = P_2 V_2 \Rightarrow P_2 = \frac{nRT_1}{V_2} = \frac{1 \times 0.082 \times 300}{(10 + 2)} = 2.05 \text{ atm}$$

(B) 正確 · ideal gas 進行恆溫膨脹的  $\Delta H = 0$

(C) 正確 · ideal gas 向真空進行恆溫膨脹過程  $\Delta S_{\text{sys}} > 0$  且  $\Delta S_{\text{surr}} = 0$  · 整個過程  $\Delta S_{\text{univ}} > 0$  · 屬於自發過程

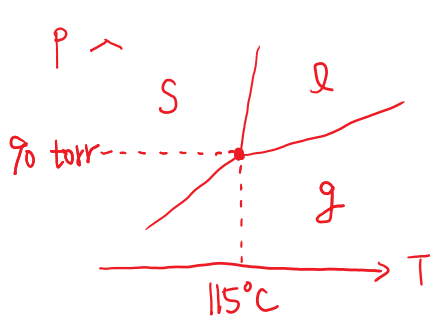
(D) 正確 · ideal gas 向真空進行恆溫膨脹過程不需要作功也不會吸熱

(E) 錯誤 · ideal gas 進行恆溫膨脹的  $\Delta E = 0$  (自發的主要原因是因為恆溫自由膨脹  $\Delta S_{\text{univ}} > 0$ )

E

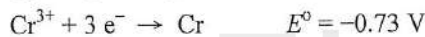
4. Compound X, like most substances, exhibits only three phases: solid, liquid, and vapor. The triple point of X is at 90 torr and 115 °C. Which of the following statements concerning the liquid and gaseous X is correct?
- (A) X(l) cannot exist at 1 atmosphere pressure.
  - (B) X(l) cannot exist above 115 °C.
  - (C) X(g) cannot exist below 115 °C.
  - (D) X(l) cannot have a vapor pressure greater than 90 torr.
  - (E) X(l) cannot exist at a pressure of 15 torr.



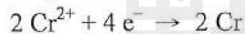


- ① 三相點的壓力為 90 torr  
表示  $X_{(s)}$  無法在 90 torr 以下穩定存在  
且  $X_{(s)}$  之蒸氣壓會大於 90 torr
- ② 三相點溫度為 115°C  
表示  $X_{(s)}$  無法在 115°C 以下穩定存在

5. Given the following half-reactions and associated standard reduction potentials:



Calculate the standard reduction potential for the following half-reaction:



(A) -0.23 V (B) -0.46 V (C) -0.85 V (D) -1.23 V (E) -1.70 V

$$\frac{(+0.5) \times 2 + (-0.73) \times 6}{4} = -0.845 \text{ V}$$

6. How many of the following statements are correct?

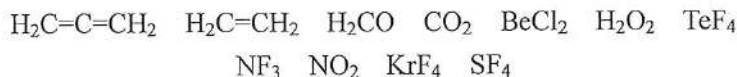
- I. All the group 13 elements are metals.  
 II. Alkaline earth metals react less vigorously with water than do alkali metals.  
 III. Salts can consist of hydrogen.  
 IV. Because Li has a more negative standard reduction potential than Na and K, it reacts most quickly with water among these three alkali metals.  
 V. BeO is amphoteric.

(A) 1 (B) 2 (C) 3 (D) 4 (E) 5

正確: II、III、V

錯誤: I、IV

7. Given the following eleven gaseous molecules:



Which of the following statements about these molecules is correct?

- (A) There are six molecules with all their atoms lying in the same plane.  
 (B) Same hybridized orbitals are used by the N atoms in  $\text{NF}_3$  and  $\text{NO}_2$ .  
 (C) Both  $\text{TeF}_4$  and  $\text{KrF}_4$  are nonpolar molecules.  
 (D) All the C-atoms in the four carbon-containing molecules use  $sp^2$  hybridized orbital.  
 (E) Both  $\text{H}_2\text{O}_2$  and  $\text{NO}_2$  exhibit resonance.



- (A) 正確 ·  $H_2C=CH_2$ 、 $H_2C=O$ 、 $CO_2$ 、 $BeCl_2$ 、 $NO_2$ 、 $KrF_4$  共六個分子所有原子共平面
- (B) 錯誤 ·  $NF_3$  為  $sp^3$  混成 ·  $NO_2$  為  $sp^2$  混成
- (C) 錯誤 ·  $TeF_4$  具有極性
- (D) 錯誤 ·  $H_2C=C=CH_2$  結構上有 2 個 carbon 屬於  $sp^2$  混成 · 有 1 個 carbon 屬於  $sp$  混成
- (E) 錯誤 ·  $H_2O_2$  沒有共振式

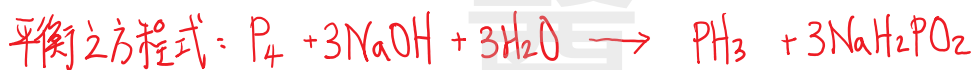
8. Ammonium benzoate is a salt formed from ammonia ( $NH_3$ ) and benzoic acid ( $C_6H_5COOH$ ). Calculate the pH of a 0.10 M solution of ammonium benzoate at 25 °C. ( $K_a = 6.4 \times 10^{-5}$  for  $C_6H_5COOH$ ,  $K_b = 1.8 \times 10^{-5}$  for  $NH_3$ ;  $\log 2 = 0.301$ ;  $\log 3 = 0.477$ ;  $\log 7 = 0.845$ )
- (A) 4.74      (B) 5.96      (C) 6.73      (D) 7.28      (E) 8.04

C

$$pH = \frac{pK_{a1} + pK_{a2}}{2} = \frac{4.2 + 9.25}{2} = 6.73$$

9. Yellow phosphorus ( $P_4$ ) undergoes disproportionation in  $NaOH(aq)$  to produce  $PH_3$  and  $NaH_2PO_2$ . If 16.0 g of  $P_4$  was used in the reaction, how many grams of  $P_4$  would behave as the oxidizing agent? (atomic weight of P = 31 u)
- (A) 12.0 g      (B) 10.0 g      (C) 8.0 g      (D) 6.4 g      (E) 4.0 g

E



由方程式可看出每 1 mol  $P_4$  進行反應, 會產生 1 mol  $PH_3$  和 3 mol  $NaH_2PO_2$   
表示 1 mol  $P_4$  中有  $\frac{1}{4}$  的磷當氧化劑,  $\frac{3}{4}$  的磷當還原劑

$$16 \times \frac{1}{4} = 4$$

10. Consider the titration of 50.0 mL of 0.100 M  $NaH_2PO_4(aq)$  with 0.100 M  $NaOH(aq)$ . For  $H_3PO_4$ ,  $K_{a1} = 7.5 \times 10^{-3}$ ,  $K_{a2} = 6.0 \times 10^{-8}$ , and  $K_{a3} = 4.8 \times 10^{-13}$ . Three pH values during the titration are listed as follows.
- (1) Before the addition of  $NaOH(aq)$ , the pH is x.
- (2) After the addition of 25.0 mL  $NaOH(aq)$ , the pH is y.
- (3) After the addition of 50.0 mL  $NaOH(aq)$ , the pH is z.
- Which of the following statements about x, y, and z is correct? ( $\log 2 = 0.301$ ,  $\log 3 = 0.477$ ,  $\log 5 = 0.699$ )
- (A)  $x < 4, y > 7$       (B)  $x > 4, z > 10$       (C)  $y > 7, z < 10$   
(D)  $y > 8, z > 9$       (E)  $x < 5, y < 7$

C

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加入 NaOH 之前:

$$pH = \frac{pK_{a1} + pK_{a2}}{2} = \frac{2.12 + 7.22}{2} = 4.67 (X)$$

加入 25 mL NaOH:

$$pH = pK_{a2} + \log\left(\frac{[HPO_4^{2-}]}{[H_2PO_4^-]}\right) = 7.22 + \log\left(\frac{0.1 \times 25}{0.1 \times 50 - 0.1 \times 25}\right) = 7.22 (Y)$$

加入 50 mL NaOH:

$$pH = \frac{pK_{a2} + pK_{a3}}{2} = \frac{7.22 + 12.32}{2} = 9.77 (Z)$$

11. Element X has only two isotopes, 1 and 2, and its atomic weight is  $y.33$  u. Of the following combinations of isotope abundance and corresponding neutron number, which is the most reasonable? (note:  $y, z, p, q$  and  $r$  are integers)

	isotope 1		isotope 2	
	abundance	number of neutron	abundance	number of neutron
(A)	50%	$p$	50%	$p + 0.66$
(B)	67%	$y$	33%	$y + 1$
(C)	75%	$q$	25%	$q + 2$
(D)	45%	$r$	55%	$r - 1$
(E)	83%	$z$	17%	$z + 2$

平均原子量為  $y.33$  u, 其中的  $0.33$  u 來自於平均中子數之小數位數

只有 (A)、(B)、(E) 三個選項符合  $0.33$  u 的小數位數

$$(A): 0.5 \cdot p + 0.5 \cdot (p + 0.66) = p + 0.33$$

$$(B): 0.67 \cdot y + 0.33 \cdot (y + 1) = y + 0.33$$

$$(E): 0.83 \cdot z + 0.17 \cdot (z + 2) = z + 0.34$$

但中子數量必須是整數, 因此 (A) 選項不正確

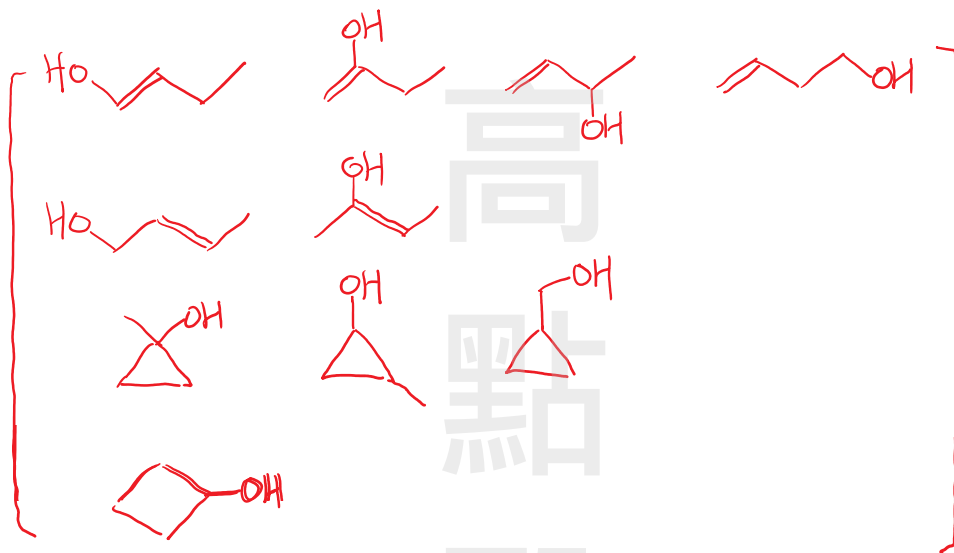
isotope 1 和 isotope 2 也不能只有中子沒有質子, 因此 (B) 選項不正確

C

12. Which of the following molecular formulae has the most structural isomers, all containing a hydroxyl group?

- (A)  $C_3H_6O$     (B)  $C_3H_8O$     (C)  $C_4H_8O$     (D)  $C_4H_{10}O$     (E)  $C_5H_{12}O$

(C): 10種 structural isomer

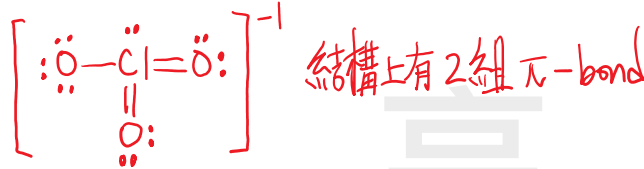


(E): 8種 structural isomer



D

13. Which of the following statements about the dominant Lewis structures of  $\text{ClO}_x^{n-}$  is correct?
- (A)  $\text{ClO}$  obeys the octet rule.
  - (B)  $\text{ClO}^-$  has 1  $\pi$  bond.
  - (C)  $\text{ClO}_2^-$  has 8 lone pair electrons.
  - (D)  $\text{ClO}_3^-$  has 2  $\pi$  bonds.
  - (E)  $\text{ClO}_4^-$  has 10 lone pair electrons



D

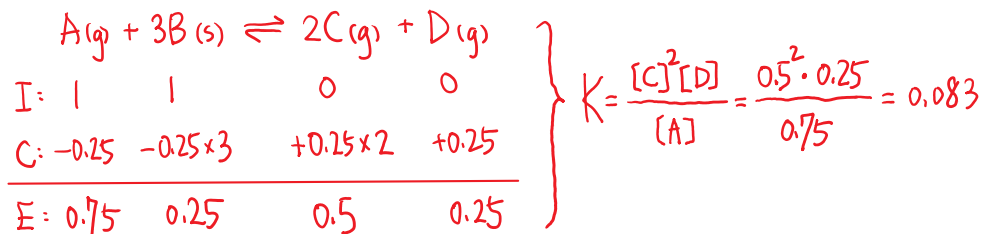
14. Which of the following statements about the van der Waals equation is incorrect?
- $$(P + \blacksquare)(V - \square) = nRT$$
- (A) The van der Waals equation describes the behavior of real gases.
  - (B)  $\blacksquare = n^2a/V^2$  and is used to compensate for the attraction force between gas molecules.
  - (C)  $\square = nb$  and is used to correct the volume of real gases.
  - (D)  $\blacksquare$  is negative for most gases.
  - (E)  $\square$  is positive for most gases.

(D) 錯誤 · 對於 real gas 來說 ·  $\blacksquare$  為 positive

D

15. If the reaction  $\text{A(g)} + 3 \text{B(s)} \rightleftharpoons 2 \text{C(g)} + \text{D(g)}$  starts with only 1 mole of A and 1 mole of B in a 1.0 L sealed reaction vessel, the equilibrium constant of this reaction is  $K$ . Which of the following statements is correct?
- (A) The expression for  $K$  of this reaction is  $([\text{C}]^2[\text{D}])/([\text{A}][\text{B}]^3)$ .
  - (B) If  $K = 1$ ,  $[\text{A}]$  is 0.5 M at equilibrium.
  - (C) If  $K = 1$ ,  $[\text{C}]$  is 0.3 M at equilibrium.
  - (D) If  $[\text{C}] = 0.5 \text{ M}$  at equilibrium,  $K = 0.08$ .
  - (E) If  $[\text{D}] = 0.25 \text{ M}$  at equilibrium,  $K = 0.17$ .

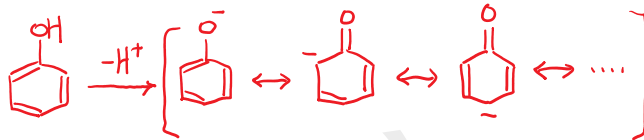
B 是 pure solid · 不需要表達在平衡定律式當中



16. Which of the following comparisons for the acidity of the following species in an aprotic solvent is correct?

E

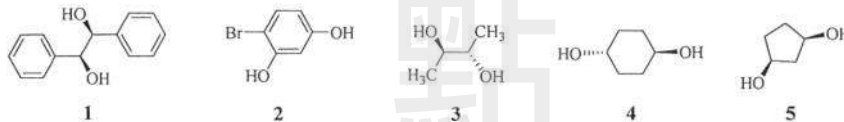
- (A) Acidity:  $\text{CH}_3\text{COO}^- > \text{HPO}_4^{2-}$  (B) Acidity:  $\text{NaNH}_2 > \text{NH}_3$   
 (C) Acidity:  $\text{HCO}_3^- > \text{HSO}_4^-$  (D) Acidity:  $\text{CH}_3\text{OH} > \text{NH}_4\text{Cl}$   
 (E) Acidity:  $\text{C}_6\text{H}_5\text{OH} > (\text{CH}_3)_3\text{COH}$



可藉由共振分散 oxygen 上的負電荷，產生的陰離子較穩定  
 對應的共軛酸之酸性較高

17. Which of the following compounds (1-5) is optically active?

A

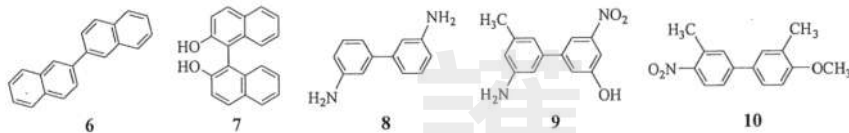


- (A) 1 (B) 2 (C) 3 (D) 4 (E) 5

有 inversion center 者：cpd 3、cpd 4  
 有內部對映面者：cpd 2、cpd 5 } 皆為 achiral 分子 (不具光學活性)

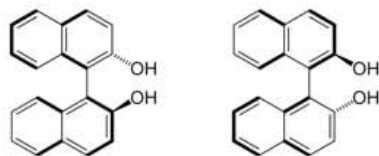
18. Which of the following compounds (6-10) is chiral?

B



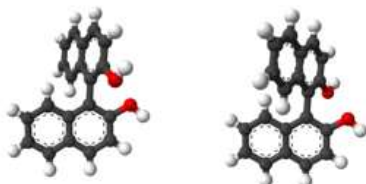
- (A) 6 (B) 7 (C) 8 (D) 9 (E) 10

有內部對映面者：cpd 6、cpd 8、cpd 9、cpd 10，屬於 achiral 分子  
 而 cpd 7 由於結構的 steric strain 影響而使兩個萘環不共平面  
 因此不具有內部對映面或反轉中心，屬於 chiral 分子

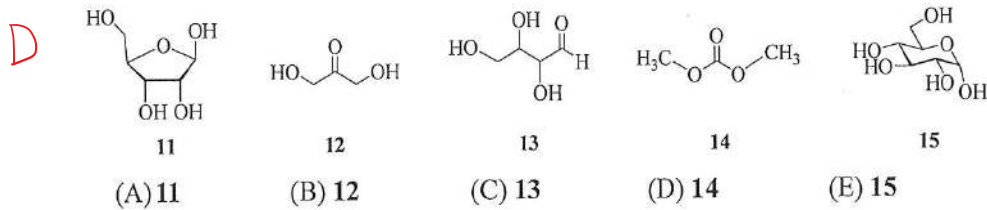


S - BINOL

R - BINOL



19. Which of the following compounds (11-15) is not monosaccharide?



monosaccharide 一般具有的分子式為  $(CH_2O)_x$ ，且結構通常為含有許多 OH 的醛或酮  
Cpd 14 並無上述結構特性，不屬於 monosaccharide

20. Each of the longest wavelength of the spectral lines recorded for two electron transitions from  $n = 2$  and  $n = 4$  of hydrogen atoms is X and Y, respectively. What is the relationship between X and Y?

- E
- (A) X:Y = 11:34                      (B) X:Y = 5:4                      (C) X:Y = 1:4  
(D) X:Y = 5:144                      (E) X:Y = 7:108

from  $n=2$  的 transition:  $n=2 \rightarrow n=1$

$$\lambda = 90 \times \frac{1}{\left(\frac{1}{1^2} - \frac{1}{2^2}\right)} = 120 \text{ (x)}$$

from  $n=4$  的 transition:  $n=4 \rightarrow n=3$

$$\lambda = 90 \times \frac{1}{\left(\frac{1}{3^2} - \frac{1}{4^2}\right)} = 1850 \text{ (y)}$$

} X:Y  $\approx$  1:15

21. As shown in Fig. 1, a container with a fixed volume at constant temperature is divided into three compartments (A, B, and C) by two partitions, which are frictionless movable partitions. Compartments A and C are filled with an equal amount of mass of gas X and Y. When two partitions stop sliding, the density of X is equal to that of Y. Which of the following statements is correct?

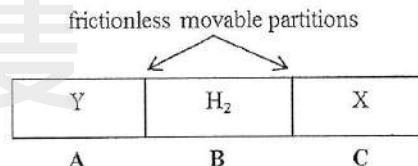


Fig. 1.

- D
- (A) Volume of gas:  $V(X) > V(H_2) > V(Y)$   
(B) Number of moles of gas:  $n(X) < n(H_2) < n(Y)$   
(C) Number of moles of gas:  $n(X) = n(H_2) = n(Y)$   
(D) The molecular mass of X is equal to the molecular mass of Y.  
(E) The molecular mass of X is smaller than the molecular mass of Y.

當過程達到平衡，A和C感受到相同壓力(皆來自於compartment B中的H<sub>2</sub>)  
由題目可知此時A和C也具有相同的溫度和密度

因此： $\overset{x}{P}(\overset{x}{Mw}) = \overset{x}{d}RT \Rightarrow$  A和C當中的氣體 X和Y有相同分子量



22. Which of the following groups of species can coexist in significant amounts in a given solution at room temperature?

A

- (A) A solution that turns methyl orange red contains  $\text{Mg}^{2+}$ ,  $\text{K}^+$ ,  $\text{SO}_4^{2-}$ , and  $\text{NO}_3^-$ .  
 (B) A solution that turns phenolphthalein red contains  $\text{Na}^+$ ,  $\text{Cu}^{2+}$ ,  $\text{HCO}_3^-$ , and  $\text{NO}_3^-$ .  
 (C) 0.1 M  $\text{AgNO}_3$  solution contains  $\text{H}^+$ ,  $\text{K}^+$ ,  $\text{SO}_4^{2-}$ , and  $\text{I}^-$ .  
 (D) 0.1 M  $\text{Na}[\text{Al}(\text{OH})_4]$  solution contains  $\text{H}^+$ ,  $\text{Na}^+$ ,  $\text{Cl}^-$ , and  $\text{SO}_4^{2-}$ .  
 (E) An acidic potassium permanganate solution contains  $\text{H}^+$ ,  $\text{Na}^+$ ,  $\text{SO}_4^{2-}$ , and glucose.

(A) 選項說明：

methyl orange 的變色範圍在 3.1~4.4。當  $\text{pH} < 3.1$  時變成紅色， $\text{pH} > 4.4$  時變成黃色。在  $\text{pH} < 3.1$  的環境不會使  $\text{Mg}^{2+}$ 、 $\text{K}^+$ 、 $\text{SO}_4^{2-}$  或  $\text{NO}_3^-$  產生沉澱，各種離子可穩定共存於溶液中。

(B) 選項說明： $\text{Cu}^{2+}$  在使酚酞變成紅色的鹼性條件下會產生  $\text{Cu}(\text{OH})_2$  沉澱。

(C) 選項說明： $\text{Ag}^+$  和  $\text{I}^-$  會產生  $\text{AgI}$  沉澱。

(D) 選項說明： $\text{NaAl}(\text{OH})_4$  會和  $\text{H}^+$  起酸鹼反應，兩者無法穩定共存。

(E) 選項說明：酸性的  $\text{KMnO}_4$  溶液會和 glucose 起氧化還原反應，兩者無法穩定共存。

23. Under the same conditions, Na, Mg, and Al of equal molar amounts are respectively added to three test tubes X, Y, and Z containing the same concentration and volume of dilute hydrochloric acid to fully react at room temperature. Which of the following three test tubes X, Y and Z must be *incorrect* in relation to the volume of gas produced?

A

- (A)  $X(\text{Na}) > Y(\text{Mg}) > Z(\text{Al})$  (B)  $X(\text{Na}) > Y(\text{Mg}) = Z(\text{Al})$   
 (C)  $X(\text{Na}) < Y(\text{Mg}) < Z(\text{Al})$  (D)  $X(\text{Na}) = Y(\text{Mg}) = Z(\text{Al})$   
 (E)  $X(\text{Na}) < Y(\text{Mg}) = Z(\text{Al})$

Mg 和 Al 在室溫下不和  $\text{H}_2\text{O}$  反應，因此

- $\text{H}^+$  限量： $Y(\text{Mg}) = Z(\text{Al})$
- $\text{H}^+$  過量： $Y(\text{Mg}) < Z(\text{Al})$

(A) 選項  $Y(\text{Mg}) > Z(\text{Al})$  不可能發生

而 (B) 選項中， $X(\text{Na}) > Y(\text{Mg}) = Z(\text{Al})$  是因為 Na 能與  $\text{H}_2\text{O}$  反應產生  $\text{H}_2$  造成  $X(\text{Na})$  可能大於  $Y(\text{Mg})$  或  $Z(\text{Al})$

24. A certain amount of  $\text{Cl}_2$  is introduced into a certain concentration of potassium hydroxide solution, where both reagents are completely consumed and heat is released. Three ionic species containing chlorine are produced from this reaction, among which the amount (n/mole) of  $\text{ClO}^-$  and  $\text{ClO}_3^-$  ions and the reaction time (t/s) are shown in Fig. 2.

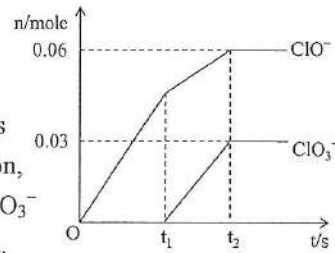


Fig. 2.

Which of the following statements is *incorrect*?

- (A) Different reactions of  $\text{Cl}_2$  and potassium hydroxide solutions may occur at different temperatures.
- (B) The number of electrons transferred in the reaction is  $1.26 \times 10^{23}$ .
- (C) The amount of  $\text{KOH}$  in the original potassium hydroxide solution cannot be determined.
- (D) The amount of  $\text{Cl}^-$  in the product is 0.21 mol.
- (E) The amount of  $\text{K}^+$  in the solution is 0.30 mol.

(A) 正確



(B) 正確, 生成  $0.06 \text{ mol } \overset{+1}{\text{ClO}}^-$  和  $0.03 \text{ mol } \overset{+5}{\text{ClO}_3}^-$   
 電子轉移總數:  $(0.06 \times 1 + 0.03 \times 5) \times 6 \times 10^{23} = 1.26 \times 10^{23}$

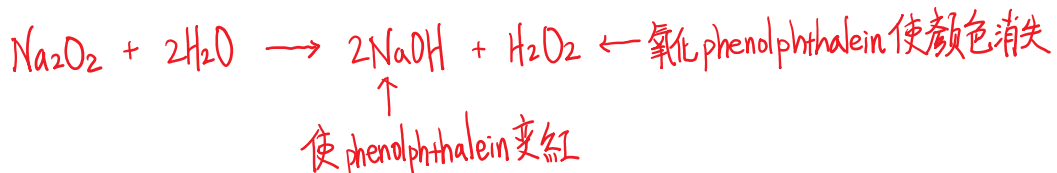
(C) 錯誤, 可由生成的  $\text{ClO}^-$  和  $\text{ClO}_3^-$  數量回推  $\text{KOH}$  數量

(D) 正確,  $\text{Cl}^-$  數量:  $0.06 \times 1 + 0.03 \times 5 = 0.21 \text{ mol}$

(E) 正確,  $\text{K}^+$  數量:  $0.06 \times 2 + 0.03 \times 6 = 0.3 \text{ mol}$

25. Based on the following experiments, which substance can prove to be bleaching?

- (A) When chlorine is introduced into a  $\text{NaOH}$  solution with phenolphthalein, the solution immediately discolors.
- (B) When a small amount of  $\text{Na}_2\text{O}_2$  powder is added to the water with phenolphthalein, the solution first turns red and then discolors.
- (C) The red color of phenolphthalein solution fades after the addition of  $\text{SO}_2$ .
- (D) When  $\text{SO}_2$  is added to an acidic solution of  $\text{KMnO}_4$ , the purple color of the solution fades.
- (E) Addition of nitric acidified  $\text{AgNO}_3$  solution to chlorine water results in white precipitate.



26. Two bottles of gas are  $\text{NO}_2(\text{g})$  and  $\text{Br}_2(\text{g})$  with the same appearance. A chemist designed a variety of identification methods:
- I. wet test paper with starch/KI, II. addition of a small amount of NaCl solution, III. addition of a small amount of  $\text{AgNO}_3$  solution, IV. addition of a small amount of water and then an appropriate amount of benzene, V. change the temperature
- Which methods can be used to distinguish  $\text{NO}_2(\text{g})$  from  $\text{Br}_2(\text{g})$ ?
- (A) I, III, IV (B) II, III, IV (C) I, II, III, IV (D) I, II, III, V (E) II, III, IV, V

- I. 兩種氣體都可以氧化 I<sup>-</sup> 產生 I<sub>2</sub>，使澱粉產生藍色，無法有效區分
- II.  $\text{NO}_2$  會與 NaCl(aq) 中的  $\text{H}_2\text{O}$  反應產生無色的  $\text{HNO}_3$  和 NO
- III. 產生  $\text{AgBr}(\text{s})$  者是  $\text{Br}_2(\text{g})$
- IV.  $\text{NO}_2$  會與  $\text{H}_2\text{O}$  反應產生  $\text{HNO}_3$  和 NO 而褪色 (沒有 Lewis acid 催化下，苯不應使  $\text{Br}_2$  褪色)
- V. 低溫下，紅棕色的  $\text{NO}_2$  會結合成無色的  $\text{N}_2\text{O}_4$

筆者認為本題極具爭議

無法認同出題老師對於題目之設計，先射箭再畫靶的出題脈絡不可取

27. At 298 K and 101 kPa,  $2 \text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2 \text{SO}_3(\text{g}) \Delta H = -197 \text{ kJ} \cdot \text{mol}^{-1}$ . At the same temperature and pressure, 2 moles of  $\text{SO}_2$  and 1 mole of  $\text{O}_2$  are introduced into a closed container, and when equilibrium is reached, the amount of heat given off is  $Q_1$ . If 1 mole of  $\text{SO}_2$ , 0.5 mole of  $\text{O}_2$  and 1 mole of  $\text{SO}_3$  are introduced into a container of the same volume, and the amount of heat given off at equilibrium is  $Q_2$ , which of the following relationships is correct?
- (A)  $Q_2 < Q_1 < 197 \text{ kJ}$  (B)  $Q_2 > Q_1 > 197 \text{ kJ}$  (C)  $Q_2 = Q_1 = 197 \text{ kJ}$   
 (D)  $Q_1 < Q_2 < 197 \text{ kJ}$  (E)  $Q_2 = Q_1 < 197 \text{ kJ}$

狀況 1: 含有 2 mol  $\text{SO}_2$  和 1 mol  $\text{O}_2$  但不含  $\text{SO}_3$   
 此時反應向右傾向較大，但不会 100% 完全反應，因此放熱量  $Q_1 < 197$

狀況 2: 含有 1 mol  $\text{SO}_2$  和 0.5 mol  $\text{O}_2$  但也含有 1 mol  $\text{SO}_3$   
 此時反應向右傾向較小，因此放熱量甚至小於  $Q_1$

結論:  $197 > Q_1 > Q_2$

28. After electrolyzing a certain concentration of copper sulfate solution with an inert electrode at a certain temperature for a certain period of time, 0.1 mole of basic copper carbonate  $[\text{Cu}_2(\text{OH})_2\text{CO}_3]$  is added to the resulting solution, and the concentration and pH are restored to exactly the same level as before electrolysis (without considering the dissolution of carbon dioxide). What is the total number of electrons transferred during the electrolysis?  
 (A) 0.4 mole (B) 0.5 mole (C) 0.6 mole (D) 0.7 mole (E) 0.8 mole

C

加入 0.1 mol  $[\text{Cu}_2(\text{OH})_2\text{CO}_3]$  相當於加入  $0.2 \text{ mol CuO}$  和  $0.1 \text{ mol H}_2\text{O}$  和  $0.1 \text{ mol CO}_2$

第一段電解  $\downarrow$  電解  $\text{CuSO}_4$

第二段電解  $\downarrow$   $\text{Cu}^{2+}$  消耗完 相當於電解  $\text{H}_2\text{O}$

不考慮  $\text{CO}_2$

因此電子轉移數：

0.2 mol  $\text{CuO}$  相當於 0.4 mol 電子轉移

0.1 mol  $\text{H}_2\text{O}$  相當於 0.2 mol 電子轉移

} 總共 0.6 mol 電子轉移

29. Acetic acid is an electrolyte. Which of the following facts indicate that acetic acid is a weak electrolyte?

- ① Acetic acid and water are miscible in any ratio.  
 ② Acetic acid solution conducts electricity.  
 ③ Acetic acid molecules are present in acetic acid solution.  
 ④ The pH of 0.1 M acetic acid solution is greater than that of 0.1 M hydrochloric acid.  
 ⑤ Acetic acid reacts with calcium carbonate to give off  $\text{CO}_2$ .  
 ⑥ The pH of 0.1 M sodium acetate solution = 8.9.  
 ⑦ When zinc grains of the same size react with the same concentration of hydrochloric acid and acetic acid solution, the acetic acid starts to produce  $\text{H}_2$  at a slower rate.

- (A) ②⑥⑦ (B) ③④⑤⑥ (C) ③④⑥⑦ (D) ②④⑥⑦ (E) ①②

(3)說明：含有  $\text{HOAc}$  分子表示沒有 100% 解離

(4)說明：pH 比相同濃度的  $\text{HCl}$  高也表示沒有 100% 解離

(6)說明： $^-\text{OAc}$  具有鹼性，可反推其共軛酸  $\text{HOAc}$  屬於弱酸  
 (如果  $\text{NaOAc}$  的  $\text{pH} = 7$  就表示  $\text{HOAc}$  是強酸)

(7)說明： $\text{HOAc}$  產生  $\text{H}_2$  速率慢是因為沒有 100% 解離， $\text{H}^+$  濃度較低的結果



30. Five different types of chemical bonds in the molecular structure of ethanol are shown in Fig. 3. Which of the following statements about reactions in which ethanol breaks bonds is *incorrect*?

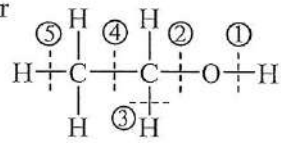
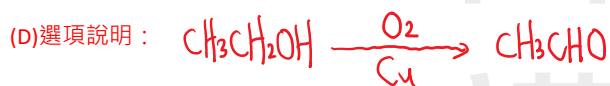
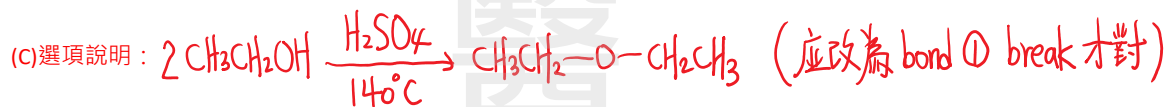
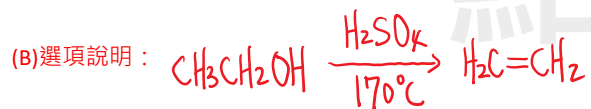
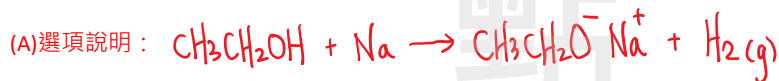


Fig. 3.

- (A) Bond ① breaks upon reaction with sodium metal.  
 (B) Bond ② and bond ⑤ break, when heating with concentrated sulfuric acid to 170 °C.  
 (C) Only bond ② breaks, when heating with concentrated sulfuric acid to 140 °C.  
 (D) Bond ① and bond ③ break upon reaction with O<sub>2</sub> catalyzed by copper.  
 (E) Only bond ① breaks, when reacting with carboxylic acids in the presence of concentrated sulfuric acid.



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## 物 理

程量子(陳宗德)老師提供

## 精選試題詳解

33. A magnetron in a microwave oven emits electromagnetic waves with frequency  $f = 2450$  MHz. Which of the following values in Gauss is closest to the magnetic field strength required for electrons to move in circular paths with this frequency?

- (A) 5                      (B) 50                      (C) 200                      (D) 600                      (E) 900

33. 解：(E)

$$\omega = \frac{eB}{m} = 2\pi f$$

$$\Rightarrow B = \frac{2\pi m f}{e} = \frac{2\pi \times 9.11 \times 10^{-31} \times 2450 \times 10^6}{1.6 \times 10^{-19}} = 0.088[T] = 880[G]$$

34. Suppose two parallel plates in Fig. 4, each has an area of  $100 \text{ cm}^2$  and are  $0.1 \text{ cm}$  apart. The capacitor is connected to a power supply and charged to a potential difference  $V_0 = 3000 \text{ V}$ . It is then disconnected from the power supply.

Which of the following values is closest to the total energy (U) stored in the capacitor in J?

- (A)  $8.0 \times 10^{-2}$                       (B)  $3.0 \times 10^{-3}$                       (C)  $6.0 \times 10^{-3}$   
(D)  $1.0 \times 10^{-4}$                       (E)  $4.0 \times 10^{-4}$

34. 解：(E)

$$C = \epsilon_0 \frac{A}{d} = \frac{1}{4\pi \times 9 \times 10^9} \times \frac{100 \times 10^{-4}}{0.1 \times 10^{-2}} = 8.85 \times 10^{-11}$$

$$U = \frac{1}{2} CV^2 = \frac{1}{2} \times 8.85 \times 10^{-11} \times 3000^2 = 3.98 \times 10^{-4} [J]$$

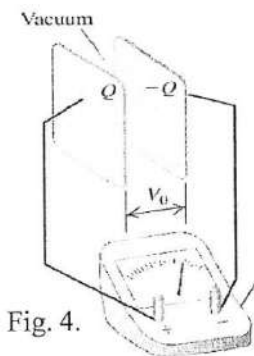


Fig. 4.

37. Which of the following values is closest to the total electric potential energy of 1 mole of  $\text{H}_2\text{O}$ ? For simplicity in calculation, here we assume a pure ionic bonding (H carries a charge  $+e$ ; O,  $-2e$ ), the O-H bond length  $\approx 100$  picometers, and the H-O-H bond angle is  $180^\circ$ .

- (A) 4.8 kJ/mol                      (B) 24 kJ/mol                      (C) 48 kJ/mol  
(D) 240 kJ/mol                      (E) 480 kJ/mol

37. 解：(E)

$$\text{由 } U = \frac{K_e Qq}{r}$$

$$U = \frac{K_e e(-2e)}{r} + \frac{K_e e(e)}{2r} + \frac{K_e (-2e)e}{r} = -\frac{7K_e e^2}{2r}$$

$$= -\frac{7 \times (9 \times 10^9)(1.6 \times 10^{-19})^2}{2 \times (100 \times 10^{-12})}$$

$$= -8.06 \times 10^{-18} [J/molecular] = -4836 [kJ/mole]$$



38. Suppose an electron is trapped in a one-dimensional infinite well of width  $L=2$  nm:  $U = 0$  from  $0$  to  $L$ ,  $U = \infty$  everywhere else. Obviously the particle can never climb out of well. Which of the following values is closest to the energy of the photon (in eV) that emits when the electron make the transition from level  $n=4$  to  $n=3$ . ( $h=6.6 \times 10^{-34}$  m<sup>2</sup>kg/s;  $m_e = 9.1 \times 10^{-31}$  kg)
- (A) 0.02      (B) 0.06      (C) 0.2      (D) 0.6      (E) 2.0

38. 解：(D)

$$E_n = \frac{n^2 h^2}{8ma^2}$$

$$= \frac{(6.63 \times 10^{-34})^2}{8 \times (9.11 \times 10^{-31})(2 \times 10^{-9})^2} n^2 = 1.5 \times 10^{-20} n^2 [J] = 0.09 n^2 [eV]$$

$$E_4 - E_3 = 0.09 \times (4^2 - 3^2) = 0.63 [eV]$$

39. A simple DC motor run by a 9.0 V battery has a 20 turn square coil with sides of length 5.0 cm and total resistance of 24  $\Omega$  (Fig. 5). When the motor spins, the magnetic field felt by the wire in the coil is  $2.0 \times 10^{-2}$  T. Which of the following values is closest to the maximum torque on the motor in m·N?

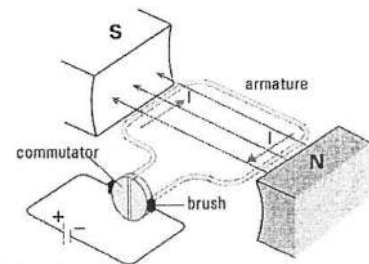


Fig. 5.

- (A)  $4 \times 10^{-4}$       (B)  $1 \times 10^{-4}$       (C)  $7 \times 10^{-3}$   
 (D)  $2 \times 10^{-3}$       (E)  $1 \times 10^{-2}$

39. 解：(A)

$$\text{由 } \vec{\tau} \equiv \vec{m} \times \vec{B}$$

$$\tau = NiAB \sin \theta$$

$$= 20 \times \frac{9}{24} \times (5 \times 10^{-2})^2 \times (2 \times 10^{-2}) \sin 90^\circ$$

$$= 3.75 \times 10^{-4} [m \cdot N]$$

41. Car A leaves point  $O$  at  $t = 0$  and travels counterclockwise along a quarter circle of radius 100 m at constant speed 30.0 m/s to reach point  $P$ . Car B is supposed to leave point  $O$  and travels to point  $P$  at the same speed but along a straight line. At what time should car B leave point  $O$  in order to arrive at point  $P$  at the same time as car A?

- (A)  $t = -4.71$  s    (B)  $t = -0.53$  s    (C)  $t = 0$       (D)  $t = 0.53$  s    (E)  $t = 4.71$  s

41. 解：(D)

$$\text{car A: } S = \frac{2\pi(100)}{4} = 30 \times (t - 0) \Rightarrow t = 5.23 [s]$$

$$\text{car B: } S = \sqrt{2} \times 100 = 30 \times (t' - 0) \Rightarrow t' = 4.71 [s]$$

car A 比 car B 所花的時間更久，為了兩車可以同時到達目的，故 car B 可以晚一點出發，則

$$\Delta t = 5.23 - 4.71 = 0.52 [s]$$

42. In a one dimensional problem, an object of mass  $m = 2.0$  kg is under effect of a resultant force  $F_x$  as shown in Fig. 7. If the object passes through the origin ( $x = 0.0$  m) with initial velocity  $v_0 = -2.0$  m/s at  $t = 0$ , what is the velocity at  $t = 4.0$  s?

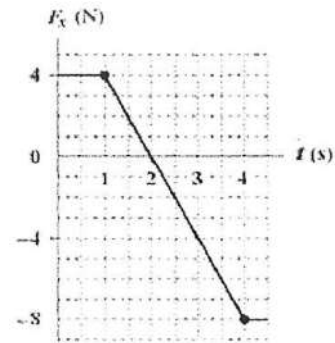


Fig. 7.

- (A) -2.0 m/s
- (B) -3.0 m/s
- (C) -5.0 m/s
- (D) -8.0 m/s
- (E) -16.0 m/s

42. 解：(B)

動量的改變為F-t圖曲線與t所圍之面積

$$\Delta p = \frac{(1+2) \times 4}{2} - \frac{2 \times 8}{2} = -2$$

$$\Delta p = m(v_f - v_i) \Rightarrow -2 = 2 \times [v_f - (-2)] \Rightarrow v_f = -3[m/s]$$

44. Two blocks,  $m_1 = 1.0$  kg and  $m_2 = 2.0$  kg, are connected by a light string as shown in Fig. 8. The radius of the pulley is 0.2 m and its moment of inertia is  $0.2 \text{ kg}\cdot\text{m}^2$ . If there is no slipping between the pulley and the string, what is the acceleration of block  $m_1$ ?

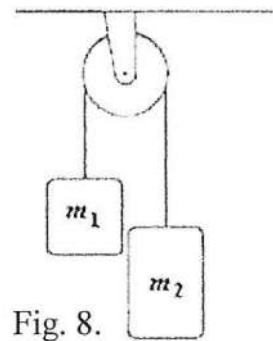


Fig. 8.

- (A) g
- (B) g/2
- (C) g/3
- (D) g/4
- (E) g/8

44. 解：(E)

$$\text{由 } \vec{\tau} = \vec{r} \times \vec{F} = I\vec{\alpha}$$

$$R(T_2 - T_1) = I\left(\frac{a}{R}\right) \Rightarrow (0.2)(T_2 - T_1) = (0.2)\left(\frac{a}{0.2}\right)$$

$$\text{由 } \vec{F} = m\vec{a}$$

$$T_2 - m_2g = -m_2a \Rightarrow T_2 - 2g = -2a$$

$$T_1 - m_1g = +m_1a \Rightarrow T_1 - 1 \cdot g = +1 \cdot a$$

$$\text{三式解得 } a = \frac{g}{8}$$

48. There is a parallel-plate capacitor of capacitance  $C_0$ . A slab of dielectric material with  $\kappa = 2$  is placed into the gap between the plates, filling the bottom half of the gap. What is the resulting capacitance?

- (A)  $\frac{1}{2}C_0$
- (B)  $\frac{3}{4}C_0$
- (C)  $\frac{4}{3}C_0$
- (D)  $2C_0$
- (E)  $3C_0$

48. 解：(C)

加入介電質前之電容

$$C_0 = \epsilon_0 \frac{A}{d}$$

加入介電質後之電容

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} = \frac{1}{\epsilon_0 \frac{A}{d/2}} + \frac{1}{2\epsilon_0 \frac{A}{d/2}} = \frac{1}{2C_0} + \frac{1}{4C_0} \Rightarrow C = \frac{4}{3}C_0$$

51. Two blocks of equal mass  $m$  placed on a frictionless flat surface are connected by a massless spring of a spring constant  $k$ , see Fig. 9. In the beginning, the spring is at its natural length, while the mass on the left is at rest and the mass on the right is moving towards right with a speed of  $v$ . The two-mass system would go on moving and oscillating relatively. During the oscillation, the maximum extension of the spring is  $L$ . What is the minimum value of the kinetic energy of the two-mass system during the oscillation?

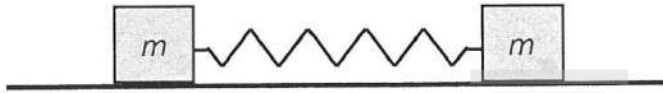


Fig. 9.

- (A)  $\frac{mv^2}{4} + \frac{kL^2}{2}$  (B)  $\frac{mv^2}{2} + \frac{kL^2}{2}$  (C)  $\frac{mv^2}{2} - \frac{kL^2}{4}$  (D)  $\frac{mv^2}{4} - \frac{kL^2}{2}$  (E)  $\frac{mv^2}{4}$

51. 解：(E)

$$\text{由線動量守恆 } \sum_i m_i \bar{v}_i = M \bar{v}_{cm}$$

$$m \cdot (0) + mv = (m + m)v_{cm} \Rightarrow v_{cm} = \frac{1}{2}v$$

由機械能守恆

$$\begin{aligned} E &= K + U \\ \Rightarrow \frac{1}{2}(2m)\left(\frac{1}{2}v\right)^2 + 0 &= 0 + \frac{1}{2}kL^2 \\ \Rightarrow K &= \frac{1}{4}mv^2 \end{aligned}$$

52. The simple harmonic motion is a general phenomenon that occurs as one perturbs a system at stable equilibrium slightly away from its potential minimum. Estimate the period of the simple harmonic motion for a particle of mass  $m$  experienced a potential energy of the form  $U(x) = a(1/x + b^2x)$  (Joule) as the particle is slightly pushed away from  $x_0 = \frac{1}{b}$  (m), where  $x$  is the spatial coordinate of the particle.

- (A)  $2\pi\sqrt{\frac{4m}{ab^3}}$  (B)  $2\pi\sqrt{\frac{2m}{ab^3}}$  (C)  $2\pi\sqrt{\frac{m}{ab^3}}$  (D)  $2\pi\sqrt{\frac{m}{2ab^3}}$  (E)  $2\pi$

52. 解：(D)

$$\begin{aligned} \frac{1}{2}mv_m^2 + U(x_0) &= U(x) \\ \Rightarrow \frac{1}{2}mv_m^2 + 2ab &= \frac{a}{x} + ab^2x \end{aligned}$$

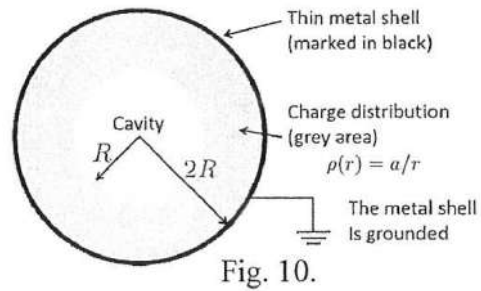
$$\Rightarrow v_m = \sqrt{\frac{2a}{mx} + \frac{2ab^2x}{m} - \frac{4ab}{m}}$$

以  $x_0$  為原點，粒子在附近作簡諧運動

$$\Rightarrow v_m = \sqrt{\frac{2a}{mx^3}}x^2 = x\sqrt{\frac{2a}{mx^3}}\Big|_{x_0} = x\sqrt{\frac{2ab^3}{m}} = x\omega$$

$$T = \frac{2\pi}{\omega} = 2\pi\sqrt{\frac{m}{2ab^3}}$$

56. Given a non-uniform charge distribution  $\rho(r) = a/r$  ( $C/m^3$ ) between two concentric spheres of radius  $R$  and  $2R$ , and it is enclosed by a thin metal spherical shell of radius  $2R$  (negligible thickness) as shown in Fig. 10, what is the surface charge density on the inner surface of the metal shell?



- (A)  $-\frac{3}{8}a$       (B)  $-\frac{3}{8\epsilon_0}a$       (C)  $-\frac{5}{18}a$   
 (D)  $-\frac{5}{18\epsilon_0}a$       (E)  $-\frac{3}{4}R^2$

56. 解：(A)

$$Q = \int_R^{2R} \rho dV = \int_R^{2R} \left(\frac{a}{r}\right) 4\pi r^2 dr = 6\pi a R^2$$

在  $2R$  處之單位面積之電荷

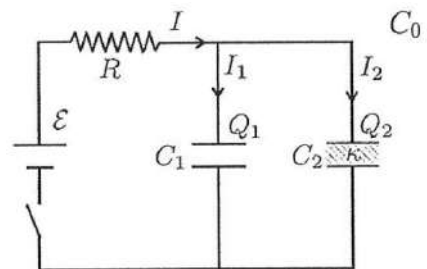
$$\sigma \equiv \frac{Q}{A} = \frac{6\pi a R^2}{4\pi(2R)^2} = \frac{3a}{8}$$

在金屬球殼內部會感應出  $\sigma_- = -\frac{3a}{8}$

在金屬球殼外部會感應出  $\sigma_+ = +\frac{3a}{8}$

(因接地則與地面之電子中和，變為無電荷)

57. A charging RC circuit consists of a battery with emf  $\epsilon$ , a resistor  $R$ , and two capacitors  $C_1$  and  $C_2$  as shown in Fig. 11. The two capacitors are identical when there are no dielectrics inserted (that is  $C_1 = C_2 = C_0$  when placed in vacuum). In order to increase the capacitance, we place a dielectric material of the dielectric constant  $\kappa$  in  $C_2$ . At  $t = 0$ , there are no charges in capacitors, and we close the switch to charge these capacitors. Which of the following statements is correct?



- (A) The charging percentage ( $Q/Q_{max}$ ) of these two capacitors would be the same at all times.  
 (B) The maximum charges stored in these two capacitors would be the same.  
 (C) The charging time would reduce if a larger resistor is used.  
 (D) The charging time would reduce if a battery with a larger emf is used.  
 (E) As more and more charges are stored in the capacitors, we expect the current flowing through the resistor is getting larger and larger.

57. 解：(A)

$$C_1 \text{ 電容 } C_1 = \epsilon_0 \frac{A}{d}$$

$$C_2 \text{ 電容 } C_2 = k\epsilon_0 \frac{A}{d} = kC_1$$

$$\text{等效電容 } C' = C_1 + C_2 = C_1 + kC_1 = (1+k)C_1$$

$$\text{RC 電路之充電 } Q(t) = C'\epsilon(1 - e^{-\frac{t}{RC'}})$$

$$C_1\text{-之電荷 } Q_1(t) = Q(t) \times \frac{C_1}{C_1 + C_2} = C'\epsilon(1 - e^{-\frac{t}{RC'}}) \times \frac{C_1}{C'} = C_1\epsilon(1 - e^{-\frac{t}{RC'}})$$

$$\Rightarrow Q_1(t) = Q_{1\max}(1 - e^{-\frac{t}{RC'}})$$

$$C_2\text{-之電荷 } Q_2(t) = Q(t) \times \frac{C_2}{C_1 + C_2} = C'\epsilon(1 - e^{-\frac{t}{RC'}}) \times \frac{C_2}{C'} = C_2\epsilon(1 - e^{-\frac{t}{RC'}})$$

$$\Rightarrow Q_2(t) = Q_{2\max}(1 - e^{-\frac{t}{RC'}})$$

$$\text{由上述可知 } \frac{Q_1(t)}{Q_{1\max}} = \frac{Q_2(t)}{Q_{2\max}}$$

58. A metal rod is pulled to the right in a uniform magnetic field  $B_0\hat{z}$  so that it accelerates at a constant acceleration  $a\hat{x}$  on rails and forms a closed circuit with a resistor  $R$  as shown in Fig. 12. For simplicity, let us say at  $t=0$ , the metal rod coincides with the resistor at  $x=0$  and is at rest. The distance between rails is  $L$ . Assume that there is no friction between the rod and rails. Which of the following statements is correct?

- (A) The emf induced by pulling the metal rod is proportional to  $t^2$ .
- (B) The force required to pull the metal rod is proportional to  $t$ .
- (C) The power dissipation in resistor is proportional to  $t^3$ .
- (D) The work done by the pulling force is proportional to  $t$ .
- (E) None of the above is correct.

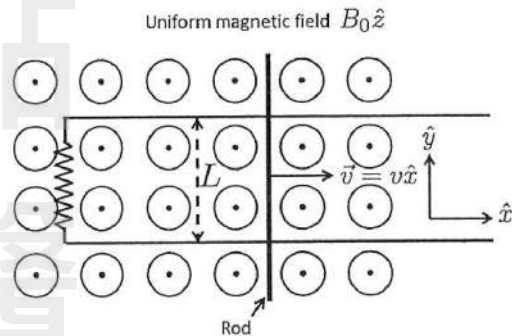


Fig. 12.

58. 解：(B)

若向右為等速度運動( $v = \text{const.}$ )，則

$$F_{\text{ext}} - iLB = m \frac{dv}{dt} = 0$$

若向右為等加速度運動( $v \propto t$ )，則

$$F_{\text{ext}} \propto t, i \propto t, \epsilon \propto t$$

$$\text{另外 } \frac{1}{2}mv^2 \propto t^2, P_R = i^2R \propto t^2$$

60. The PV curve for the van der Waals equation at a fixed temperature is plotted in Fig. 13. In this case, the liquid phase can coexist with the gas phase at pressure  $P_c$ . The pressure  $P_c$  intercepts with the PV curve at three points:  $a$ ,  $c$ , and  $e$ , respectively. And the slope of the PV curve vanishes at  $b$  and  $d$ . Which of the following statements is correct?

- (A) For pressure a bit higher than  $P_c$ , it is impossible to have a stable gas phase.
- (B) For pressure a bit lower than  $P_c$ , the gas phase is more stable than the liquid phase.
- (C) The region  $a \rightarrow b$  is the supercooled liquid region.
- (D) The region  $b \rightarrow c \rightarrow d$  corresponds to a fluid with a positive compressibility.
- (E) None of the above.

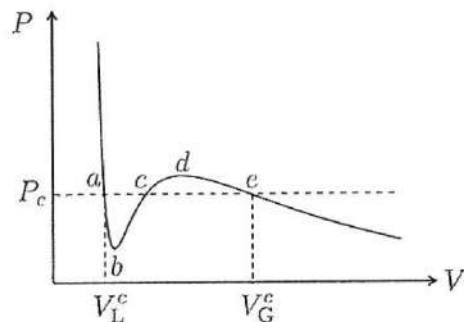


Fig. 13.

60. 解：(B)

$P > P_c$  漸漸產生完整活潑的氣態

$P < P_c$  存在穩定的氣態

van der Waal equation  $(P + \frac{a}{V^2})(V - b) = kT$

主要描述理想氣體，它考慮了分子的大小及分子間交互作用力，與超冷液體無關。 $b \rightarrow c \rightarrow d$ 為汽化，負壓縮。

高  
點  
醫  
護

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